

NNJ06TA25C

Crew Exploration Vehicle – (CEV)

Attachment J-1

Modification ~~9~~⁹⁴

ATTACHMENT J-1

STATEMENT OF WORK

May 2009

INTRODUCTION

The Crew Exploration Vehicle (CEV) is the spacecraft that NASA plans to use to send human and cargo items into space and to return them to earth. The CEV is an element of the overall Constellation Program that includes launch vehicles, spacecraft, and ground systems needed to embark on a robust space exploration program. This space exploration program will advance the Nation's scientific, security, and economic interests.

Scope

The Contractor shall develop and certify the CEV System to meet the International Space Station (ISS) mission requirements. The Contractor shall develop and deliver a lunar block change plan that shows extensibility of the CEV System design to meet lunar sortie and lunar outpost mission requirements. The lunar block change plan will identify those system design items that have a development deferral to a future contract action. During lunar missions, the CEV is used to carry the crew to low earth orbit (LEO) for rendezvous with other elements for the lunar missions and also serve as the return-to-earth vehicle for the crew. The Contractor will modify and certify the ISS CEV design as required to support lunar mission requirements. The Contractor shall deliver the CEV spacecraft configurations below per requirements in the CXP-72000, System Requirements for the Crew Exploration Vehicle Element (CEV SRD).

The following more clearly defines the different configuration variants of the CEV Spacecraft:

1. Block 1A is a crewed, pressurized cargo vehicle for Low Earth Orbit (LEO) (including ISS crew change out) missions. This configuration includes:

- A habitable Crew Module (CM)
- A Service Module (SM) which also includes the Spacecraft Adapter (SA) which interfaces with the Crew Launch Vehicle (CLV)
- A Launch Abort System (LAS) to provide a method for crew abort

2. Block 2 is a crewed, pressurized cargo vehicle for lunar missions. It uses a habitable CM, LAS, SM, and SA to support lunar missions.

CxP-70072-ANX 01, Constellation Systems Management Systems Plan, Annex 01: Common Glossary and Acronyms provides a detailed listing of terms used in this Statement of Work.

CEV Implementation Strategy

The CEV implementation strategy requires a detailed implementation schedule to design the spacecraft, and implement, certify, and deliver it. NASA will work closely with the Contractor to develop the details of an implementation strategy that maintains the highest standards for safety, reliability, and mission assurance. Ways that NASA will work closely with the Contractor include the following: NASA will participate in daily management and design meetings and decisions, NASA will work with the Contractor on the shop floor during development, NASA will participate in the Contractor Material Review Board (MRB) process, as described in CXP 70059-SR&QA Requirements, in order to help prevent stop-work conditions, and NASA will work with the Contractor in the test facilities during integration and test activities. The purpose of the level of participation is for access to NASA for timely decisions.

Crew Exploration Vehicle – (CEV)

Modification 904

NASA will provide the detailed oversight of all spacecraft design activities. However, the Contractor will retain responsibility for delivery of a design that meets the requirements. The detailed process discussion to accomplish this can be found in CxP-72008, Crew Exploration Vehicle Project Plan. Some areas of spacecraft design will be provided by NASA and NASA will perform independent activities for requirements validation and design certification in other areas. In these areas NASA will establish design requirements teams to integrate the activities of NASA and the Contractor. The Contractor will participate in and support these design requirements teams. NASA has responsibility for all GFE provided equipment.

The Contractor will deliver a design that ensures simplicity, minimizes life cycle cost and addresses all aspects of human spacecraft development, production, certification and operations. The Contractor will design, develop, certify, and deliver the hardware required to achieve ISS mission requirements in Schedule A. The Contractor shall develop a lunar block change plan that shows extensibility of the CEV System design to meet lunar sortie and lunar outpost mission requirements. The lunar block change plan will identify those system design items that have a development deferral to a future contract action. The concept is to develop a “common” design for the spacecraft variants, where the vehicle can be utilized for both Lunar and ISS requirements. The common design and life cycle approaches will lead to an effective implementation of subsystem and spacecraft deliveries.

The Contractor is expected to develop and verify ISS mission software during Schedule A, with lunar mission software being developed in future contract action with other lunar block upgrades. However, lunar mission software requirements must be evaluated to ensure the command and data handling hardware can accommodate the additional software required for lunar missions, as well as other mission objectives. The “common” vehicle design shall be configured to accommodate integrating the future lunar block upgrades to achieve the lunar mission objectives while remaining within the vehicle requirements constraints.

NASA will perform the CEV ground, flight, and training operations; design and develop CEV ground operations facilities, facility systems, and NASA-provided ground support equipment (GSE); and provide high-fidelity simulators and trainers. Further, NASA will conduct flight testing to demonstrate vehicle performance characteristics. NASA will lead a joint NASA and Contractor Combined Test Team (CTT) that consists of representatives from all participating test organizations. In support of the NASA operations, risk reduction flight testing, and safety and mission assurance activities, the Contractor must provide the necessary data products and expertise as detailed in the SOW.

NASA will use the technical Data Requirements Documents (DRDs) to sustain and operate the CEV over the life of the Project. It is NASA's intent to use the technical DRDs to document the CEV requirements, design, and certification activities.

Contract Structure

To help differentiate the type of activities that comprise the Phase 2 contract, NASA has developed multiple “schedules.” These include:

1. Schedule A (DDT&E). This includes all design, development, test and evaluation activities to certify variants 1A and 1B as well as the production activities for the first actual flight module of the 1A variant, along with other deliverables described in this SOW. Schedule A incorporates

Crew Exploration Vehicle – (CEV)

Modification ~~9~~⁹⁴

completion form and indefinite delivery, indefinite quantity (IDIQ) paragraphs. All paragraphs are completion form unless specifically marked as "IDIQ."

2. Schedule B (Production). This includes production of all block variants.

3. Schedule C (Sustaining Engineering). This includes any new DDT&E effort required beyond the scope of Schedule A, such as the Block 2 variant.

This statement of work applies to Schedule A only. Descriptions of other contract schedules are provided for reference only.

1 PROJECT MANAGEMENT

The Contractor shall develop, implement and maintain a set of common project management processes, systems and data deliverables to be utilized for all contract schedules (A, B and C) throughout the life of the contract.

1.1 Project Management and Administration

An anchoring capability of the Constellation Program is a human-rated CEV that will carry human crews from Earth into space and back again. Coupled with transfer stages, landing vehicles, and surface exploration systems, the CEV will serve as an essential component of the architecture that supports human voyages to ISS, the Moon, and beyond.

- a) The Contractor shall design, develop, certify, and deliver the hardware and software required to achieve the LEO and ISS mission requirements. The Contractor shall develop a lunar block change plan that shows extensibility of the CEV System design to meet lunar sortie and lunar outpost mission requirements. The lunar block change plan will identify those system design items that have a development deferral to a future contract action.
- b) The Contractor should minimize life cycle cost in the design, development, certification, and delivery of the hardware and software required to achieve the LEO and ISS mission requirements in accordance with paragraph 1.1a.
- c) The Contractor shall ensure crew/ground safety while meeting system performance requirements and achieving mission objectives.
- d) The Contractor shall design the CEV System to accommodate all the design reference missions defined in CXP-70007, Constellation Design Reference Missions (DRM).
- e) The Contractor shall design the CEV System to the requirements and terms specified in CXP-72000, System Requirements for the Crew Exploration Vehicle Element (CEV SRD).
- f) The Contractor shall implement designs for the CEV spacecraft and ground systems to achieve efficient and effective operations.
- g) The Contractor shall perform to the negotiated cost, schedule, and technical baseline.
- h) Reserved
- i) The Contractor should maximize the use of existing technology in the design of the CEV, unless new technology is required to meet NASA requirements.
- j) The Contractor shall base the vehicle design on an open system architecture.
- k) The Contractor should qualify components, subsystems, modules, and systems by test, to the maximum extent possible.
- l) The Contractor shall provide a CEV System that shall have a lifecycle that ends no less than 20 years after the first human flight.
- M) Contractor shall develop and document a lunar block change plan that shows extensibility of the CEV System design to meet lunar sortie and lunar outpost mission requirements in accordance with **DRD CEV-M-006 Lunar Block Upgrade Plan**. The plan will identify those system design items that have a development deferral to a future contract action. The Lunar Block Upgrade plan shall be presented at each major design review. The Lunar Block Upgrade activities to be conducted in a future contract action include:
 - Lunar Software (Non C³I)
 - Lunar C³I Software
 - LSAM Power Transfer Unit

Crew Exploration Vehicle – (CEV)

Modification 9~~94~~

- Phase Change Material
- M-5 Parachute Material Change
- Ultra Thin Solar Array Cells
- Structures Optimization
- Avionics Technology Insertion
- Lithium Polymer Batteries
- Lunar Navigation Targets
- Harnessing

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-M-006: Lunar Block Upgrade Plan

1.1.a Project Management, Systems, Planning and Reporting

- a) The Contractor shall implement an organizational structure for the management, coordination, and control of contract activities including the project's cost, schedule, performance, risks, contracts, and subcontracts using as guidance ISO 14300-1, Space Systems - Program Management - Part 1: Structuring of a Program. The Contractor shall develop and implement a project management plan that covers all aspects of project management for the CEV Project in accordance with **DRD CEV-M-001**, *CEV Prime Project Management Plan*. The contractor shall incorporate the proposed Streamlining Plan in **DRD CEV-M-001**, *Prime Project Management Plan*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-M-001: CEV Prime Project Management Plan

1.1.b Performance Management Reviews and Performance Metrics

- a) The Contractor shall conduct quarterly Performance Management Reviews (PMRs) with the Crew Exploration Vehicle Project Office (CEVPO) in accordance with **DRD CEV-M-002**, *Performance Assessment Plan, Reports and Management Reviews*. The reviews shall provide insight into the Contractor's, subcontractors', and vendors' overall technical, schedule, and cost performance and status.
- b) The Contractor shall define the metrics, to be approved by government, in accordance with the **DRD CEV-M-002**, *Performance Assessment Plan, Reports and Management Reviews*. The Contractor shall update the metrics and performance data monthly and make it available for NASA review in the Contractor's collaborative environment and during working-level discussions. The Contractor shall present the metrics and performance data at the PMRs.
- c) The Contractor shall recommend the technical performance parameters, to be approved by NASA, in the Performance Assessment Plan. The Contractor shall status the technical performance parameters quarterly in their Performance Assessment Reports.
- d) The Contractor shall report on each SOW and SRD "should" statement at the PMR until the "shoulds" are satisfactorily accomplished.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-M-002: Performance Assessment Plan, Reports and Management Reviews

1.1.c External Relationships***1.1.c.1 Associate Contractors***

- a) When the working environment requires interaction with other NASA contractors, the Contractor shall establish cooperative relationships with other NASA contractors, defined as associate contractor relationships. Associate relationships are required for expeditious exchange of management and technical data among NASA contractors.

1.1.c.2 NASA Centers

- a) The Contractor shall establish cooperative relationships at the NASA centers to provide support (e.g. technical analyses, data, etc.) or understand NASA GFE and associated data deliverables (reference SOW paragraph 6.b), schedules, interfaces, and interactions. The contractor shall work jointly with NASA to establish contractor/NASA GFE integration teams. These relationships shall be documented in accordance with **DRD CEV-M-001**, *CEV Prime Project Management Plan*.
- b) The Contractor shall provide resident office space, including phone, computer, and desk space, to accommodate NASA program office personnel.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-M-001: CEV Prime Project Management Plan

1.1.d Internal/External Project Review Support

- a) The Contractor shall develop briefing materials and analyses for CEV System meetings with various internal and external review groups. Examples of these internal and external groups include the flight technique panels, Aerospace Safety Advisory Panel (ASAP), Inspector General/Government Accountability Office (IG/GAO), and cost assessments teams.
- b) The Contractor shall prepare and present various topics, such as CEV Project technical, cost, and schedule status, specific safety or risk issues, design and development issues, and responses to external inquiries, as directed by NASA.

1.1.e Security Management

Security management includes management of information technology security, physical/facility security, personnel security, flight vehicle security and flight test article security.

- a) The contractor shall use the following standards and requirements documents for developing and executing all security management processes and products:

Crew Exploration Vehicle – (CEV)

Modification 994

CxP 70070-ANX05-01, CxP Program Management Plan Annex 5: Security Management Plan, Book 1: Information Technology Functional Security Requirements

CxP 72008, CEV Project Plan, section 4.10 and associated children.

NASA will be responsible for encryption handling key management, storage, COMSEC custodial activities, and operational integration at KSC, CAIL and Plumbrook.

- b) The following documents are provided for informational purposes for the contractor to support development of all security management processes and products:

CxP 70070-ANX05-Book2, Constellation Program Management Plan Annex 5: Security Management Plan, Book 2: Information Technology (IT) Security Architecture

1.2 Business Management

1.2.(a) Financial Management

Financial Management provides summary-level cost reporting by fund source, Work Breakdown Structure (WBS), elements of cost and workforce including labor equivalent personnel (EP), overhead, and other direct and indirect costs.

- 1) The Contractor shall develop, deliver, and implement monthly financial management reporting in accordance with **DRD CEV-B-001**, *Financial Management Report* (NASA Form 533).
- 2) The Contractor shall provide project-wide data once a year to be used in NASA's budget planning process (e.g., program operating plan (POP) budget calls). The Contractor shall provide an annual Operating Plan (OP) update to that data for the upcoming fiscal year as requested by NASA. NASA will specify the format and content of the Contractor's inputs and rationale.
- 3) Upon request by NASA, the Contractor shall provide project-wide budget data a maximum of three times per year. This data will be used for the purposes of gathering budget impacts for various re-planning scenarios. NASA will specify the format and content of the Contractor's inputs and rationale.
- 4) The Contractor shall provide property financial reports in accordance with **DRD CEV-B-004**, *Property Financial Reporting*.
- 5) The Contractor shall provide Rough Order of Magnitude (ROM) estimates as requested to support the NASA decision making process. ROM estimates shall be delivered to NASA within 7 days of the formal request unless the contractor notifies NASA within 2 days of request receipt that the ROM will require more time due to effort required to bound the scope, additional reviews required, or significant complexity. The contractor shall use best available estimating techniques given the groundrules and assumptions provided by NASA. Prior to delivery to NASA, ROM estimates will be reviewed by the contractor technical community.

Deliverables

The Contractor shall deliver and maintain the following document(s):

Crew Exploration Vehicle – (CEV)

Modification 904

- DRD CEV-B-001: Financial Management Report (533)
- DRD CEV-B-004: Property Financial Reporting

1.2.(b) *Workforce Reporting*

Workforce Reporting provides workforce information by geographic location.

- 1) The Contractor shall develop, deliver and implement workforce data in accordance with **DRD CEV-B-002, Workforce Reporting**.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-B-002: Workforce Reporting

1.2.(c) *Integrated Baseline Review (IBR)*

- 1) The Contractor shall perform an Integrated Baseline Review (IBR) with NASA to establish the contract baseline. Subsequent baseline reviews will be required by NASA to update the performance measurement baseline when the contract has a significant restructure or change in cost phasing. The IBR shall include the following accomplishment criteria and subsequent baseline reviews should identify only changes:
 - Project organization fully established with cost control accounts and organization members identified, including interfaces and interactions with NASA. Organization and teaming roles and responsibilities defined.
 - Organizational staffing plans in place
 - IMS review
 - Risk management system and process review
 - Metrics baselined
 - Earned value management system and process review
- 2) The Contractor shall ensure the technical contents of work packages and control accounts are consistent with the scope of work defined in the WBS, SOW and SRD.
- 3) The Contractor shall work jointly with NASA to develop and document an integrated performance measurement baseline. This baseline consists of all contract work including the integration of GFE.
- 4) NASA will provide agreed-to specific GFE performance measurement baseline data.
- 5) The Contractor shall provide a logical, resource-loaded, integrated/interdependent sequence (i.e. predecessor/successor network) of tasks supporting the contract schedule.
- 6) The Contractor shall demonstrate to NASA that metric collection methods are in place to monitor agreed-to requirements of the contract.

1.2.(d) *Cost Performance Report*

The Cost Performance Report (CPR) will be used to provide information for: (1) integrating cost and schedule performance data with technical performance measures, (2) assessing the magnitude and impact of actual and potential problem areas causing significant cost and schedule variances, and (3) providing valid, timely status information to the CEV Project.

- 1) The Contractor shall establish, maintain, and use in the performance of this contract, an integrated earned value management system in accordance with ANSI/EIA-748-98, Earned Value Management Systems.

Crew Exploration Vehicle – (CEV)

Modification 904

- 2) The Contractor will perform earned value analysis and shall capture, maintain, and provide NASA access to the earned value analysis data. The earned value analysis data, at both the cost account and overall project-level, shall be presented as part of the quarterly PMR. Reference **DRD CEV-M-002**, *Performance Assessment Plan, Reports and Management Reviews*. In addition, the contractor shall provide electronic access to the Contractor's weekly earned value data.
- 3) The Contractor shall develop, deliver and implement CPR data in accordance with **DRD CEV-B-003**, *Cost Performance Report*, and shall support informal working-level discussions on the content.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-B-003: Cost Performance Report

1.2.(e) Life Cycle Cost Management

- 1) The Contractor shall capture, maintain, and provide access to life cycle cost analysis data in the NASA ICE as it evolves through the project life cycle. Life cycle cost definitions to be used in the analysis are defined in Attachment J-5, Appendix 1, Life Cycle Cost Analysis. Life cycle cost analysis data for DDT&E and operability shall be generated and presented at each major design review (e.g. SDR, PDR, CDR) and at each quarterly PMR. These presentations shall include the latest LCC estimate, as well as a detailed discussion of the impact from the current design, design and operations changes since the last review, and the rationale for the changes. In addition, the contractor shall utilize an integrated management assessment tool to perform affordability analysis to support life cycle cost management. Reference SOW paragraph 2.4 Integrated Analysis.

1.2.(f) Contracts Management

- 1) The Contract Management organization shall develop, review, interpret, negotiate, modify and administer the Project Orion contract. Contracts Management is the primary point of contact with the Orion NASA Contracting Officer(s), the delegated Defense Contracting Management Agency (DCMA) and the delegated Defense Contract Audit Agency (DCAA). Contracts Management shall resolve and document contract issues. Contracts Management shall ensure that Contract requirements are fully defined and implemented by the contractor team.

1.3 Configuration Management and Data Management**1.3.(a) Configuration Management**

- 1) The Contractor shall develop and implement Configuration Management (CM) processes and systems.
 - o The Contractor CM process and system shall use MIL-HDBK-61A, Military Handbook Configuration Management Guidance, as guidance.
 - o The Contractor's CM process and system shall provide the following: (1) configuration identification, (2) configuration control, (3) configuration status accounting, and (4) configuration management verification and audits.
 - o The Contractor CM plan shall define how the *Software Configuration Management Plan* (see **DRD CEV-T-006**) supports this CM process and system.

Crew Exploration Vehicle – (CEV)

Modification 994

- o The Contractor shall work with NASA to develop a configuration management process that also integrates with the Constellation Program and complies with the CXP-02007, Constellation Nomenclature Plan. The Contractor CM process and system will be approved by NASA.
- 2) The Contractor shall integrate the CM system across all CEV project elements including modeling and simulation, engineering drawing development and release, manufacturing, test equipment and test articles, operations, and quality, as well as acquisition organizations including customer and vendor CM systems.
- 3) The Contractor shall implement and maintain a configuration status accounting system that provides information defining and maintaining the as-designed and as-built configuration of the system hardware and software and the status of changes to this configuration.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- **DRD CEV-M-003:** Configuration Management Plan and Reports

1.3.(b) Data Management

- a) The Contractor shall develop and implement Data Management (DM) processes and systems.
 - o The Contractor's DM process and system shall provide the following: (1) data identification, (2) data control, (3) data status accounting, and (4) data management verification and audits.
 - o The Contractor shall work with NASA to develop a data management process that also integrates with the Constellation Program. The Contractor DM process and system will be approved by NASA.
- b) The Contractor shall integrate the DM system across all CEV project elements such as modeling and simulation, engineering drawing development, manufacturing, test equipment and test articles, operations, and quality, as well as acquisition organizations including customer and vendor DM systems.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- **DRD CEV-M-004:** Data Management Plan

1.4 Risk Management

- a) The Contractor shall identify, evaluate, manage, and control the safety, technical, cost, and schedule-related risks associated with all aspects of the CEV Project in accordance with CXP-72091 Orion Integrated Risk Management Plan.
- b) The Contractor shall provide substantiating data for each risk identified in accordance with **DRD CEV-M-005, Risk Management Plan and Reports.**
- c) The Contractor shall substantiate each identified risk in the form of historical information, and analysis. These analyses and information may be integrated with Probabilistic Risk Assessment (PRA) analysis, as appropriately applied to high risk hardware/software development and operations. Reference S&MA **DRD CEV-S-010, Probabilistic Risk Assessment Results.**

Crew Exploration Vehicle – (CEV)

Modification 994

- d) The Contractor shall communicate and elevate multi-element and external interface risks to the CEV Project office for the purpose of multi-element risk integration.
- e) The Contractor shall perform integrated risk analysis, mitigation, tracking/control for the CEV Project office. This effort is for the purpose of communication of external interface and multi-element risk integration data for the Constellation-level risk management process.
- f) The Contractor shall manage risks utilizing a risk management tool. The Contractor shall integrate their risk management tool with ICE.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- **DRD CEV-M-005:** Risk Management Plan and Reports

1.5 Information Technology Management

For IT applications, other than mission-specific software, the Contractor shall:

- o Where cost effective to NASA, use Commercial-Off-The-Shelf (COTS) and existing Government Off-The-Shelf (GOTS) products.
- o Ensure compatibility with existing NASA applications and systems.
- o Comply with NASA requirements for NPR 7150.2, NASA Software Engineering Requirements for the appropriate software classes, limited to classes E, F, and G.

1.5.(a) NASA Integrated Collaborative Environment (ICE)

The NASA Integrated Collaborative Environment (ICE) is the primary means of sharing, reporting, collecting, recording, and accessing project information between NASA, the CEV Contractor, subcontractors and authorized Government personnel connected with the CEV Project. ICE provides secure, real-time collaborative access to a single source of management information, product information, and technical data. ICE is the principal mechanism for integrating a project's digital information management environment.

- 1) The Contractor shall use ICE for delivery of all data.
- 2) The Contractor shall use the interactive collaborative configuration management and document management environments of ICE for configuration management of CEV project directives and change control activities.
- 3) The Contractor shall comply with Attachment J-14, ICE Operating Environment.
- 4) The Contractor shall implement the ICE interface using one of the two options described in J-14, ICE Operating Environment, Section II, Data Access Requirements.
- 5) The Contractor's collaborative environment shall be available within 30 days of contract award.
- 6) The Contractor's collaborative environment shall be updated with the latest status information based on the Contractor-determined interval(s) and as approved by NASA.
- 7) Non Deliverable information such as week to week coordination, working level analysis, action item responses, etc shall be transmitted via an LM established data sharing system (eg project link).

1.6 Reserved

1.7 Integrated Schedule Management

1.7.(a) Integrated Master Plan (IMP)

- a) The Contractor shall develop and maintain an Integrated Master Plan (IMP), as Attachment J-15 of this contract, which delineates Schedule A, B and C activities. All changes to the IMP shall be via bilateral modification.
- b) The Contractor shall manage the execution of the CEV System using the IMP. The Contractor shall report on contract progress in accordance with the IMP at each PMR.

1.7.(b) Integrated Master Schedule (IMS)

- a) The Contractor shall develop, maintain, and provide NASA access to an Integrated Master Schedule (IMS). The Contractor shall use this schedule for day-to-day management of the contract tasks. Reference contract Clause H.12, Electronic Data Access.
- b) The Contractor shall create and maintain a schedule that supports automated time phasing of tasks, and is a resource loaded, predecessor/successor structured, networked schedule, with critical path identification and schedule assessment capability. The Contractor shall incorporate delivery schedules for NASA products and data into their IMS and provide an integrated IMS that reflects the entire CEV project scope.
- c) The Contractor shall maintain and update the IMS to reflect changes in the IMP and deliver it in accordance with Section 13.1 of **DRD CEV-B-003, Cost Performance Report**.
- d) The Contractor shall utilize the IMS as the source for schedule data delivered to NASA.
- e) The Contractor shall integrate all risk mitigation activities into the IMS.
- f) The contractor shall provide monthly reporting of risk-based critical path analysis (via CEV-B-003, CPR, Format 5 Explanations and Problem Analysis) including but not limited to Monte Carlo based analysis, analyst judgment and proposed mitigation strategies for line items that drive the risk-based critical path. The contractor shall perform validation of logic links within the schedule using an automated tool.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-B-003: Cost Performance Report

1.8 Special Studies (IDIQ)

- a) The Contractor shall perform special CEV-related studies and analyses as directed by NASA. The Contractor shall define the resources required as part of their response to NASA's request for a task order plan. The trade studies and analyses resulting from special studies shall also include the impact to system safety and life cycle cost.

2 CEV VEHICLE INTEGRATION

CEV Vehicle Integration consists of the technical and management efforts of directing and controlling the integrated CEV System Engineering and Integration effort to achieve a solution that satisfies all CEV Project requirements and otherwise balances performance, cost/affordability, schedule, and risk. This effort includes the development of upgrade paths for future missions and integration of the CEV System with all elements of the Constellation Program. This element also includes task efforts in managing Technical Reviews required by NASA.

2.1 VI Management and Administration

Vehicle Integration Management and Administration consists of the efforts for planning, organizing, directing, coordinating, controlling, and approval processes used to accomplish Vehicle Integration objectives. Vehicle Integration consists of the efforts to manage the Contractor's systems engineering and integration activities and to manage the Contractor's participation in NASA-led Constellation Program systems engineering and integration activities in accordance with NASA requirements and the Contractor's documented plans.

- a) The Contractor shall manage their systems engineering and integration activities consistent with CxP-72008, Crew Exploration Vehicle Project Plan.
- b) The Contractor shall participate in Crew Exploration Vehicle Project and Constellation Program systems engineering and integration activities in accordance with CxP-72008, CEV Project Plan.
- c) The Contractor shall implement plans for managing technical data products, processes and organizational roles and responsibilities used to accomplish their systems engineering and integration activities and document their plans in the Contractor's PMP (DRD CEV-M-001, CEV Prime Project Management Plan).

2.1.(a) Technical Reviews

- 1) The Contractor shall support the planning and execution of technical integration reviews conducted by NASA. The Contractor shall support integrated analysis and assessment efforts in support of the integration reviews to identify and resolve integration issues with other Constellation elements, as required.
- 2) The reviews conducted by NASA are contained in the Integrated Master Plan as defined in Attachment J-15. At these reviews, the Contractor shall develop and present data and respond to Review Item Discrepancies (RIDs) and identified CoFR exceptions.

2.2 CEV Requirements Definition and Management

- a) The Contractor shall address all life cycle processes including development, manufacturing, test, distribution, operation, support, training, and disposal to derive a complete requirements (functional) baseline and functional architecture.
- b) The Contractor, in conjunction with NASA, shall allocate the CXP-72000, Systems Requirements for the Crew Exploration Vehicle Element (CEV SRD), and External IRDs to the Spacecraft and ground support equipment. The Contractor shall document the requirements developed from this process in the Spacecraft <System> Requirements Specification and the Ground Support Equipment <System> Requirements Specification per **DRD CEV-T-031**, CEV <Level> Requirements Specification, and in **DRD CEV-T-032**, CEV

Crew Exploration Vehicle – (CEV)

Modification 994

Specification and Drawing Trees. The Contractor shall integrate Module Specific Drawing Trees identified in Sections 6.1.2, 6.2.2, 6.4.2 into the Integrated Stack Drawing Tree.

- c) The Contractor shall document the functional decomposition, requirements allocation, and design to the component level in **DRD CEV-T-033, Architecture Design Document**.
- d) The Contractor shall provide a requirements database within **CRADLE®** to maintain bi-directional requirements traceability from the CEV System level/EIRs and the CEV subsystem level requirements throughout the requirements allocation process to the component level. The **CRADLE®** database shall also include a functional model to which the requirements are linked. The Contractor shall provide NASA access to this capability through NASA ICE and provide traceability reports at all milestone reviews to verify requirements traceability. This traceability shall be maintained and continue through the design, procurement specifications, hardware and software configuration items requirements, and verification of the requirements and results. Traceability shall be documented per **DRD CEV-T-034, Requirements Traceability Report**.
- e) The Contractor shall configuration manage the allocated requirements baseline and architecture throughout the performance period of this contract in accordance with Section 1.3 (a) Configuration Management.
- f) The Contractor shall perform iterative and on-going analyses to validate the allocation of requirements and document the results in **DRD CEV-T-010, System Performance Analysis Report**.
- g) The Contractor shall assign each requirement an owner who is responsible for ensuring that the requirement is 1) consistent with evolving requirements and the design baseline; 2) complete and sufficient relative to similar requirements; 3) correctly and clearly written; 4) verifiable via test or other approved method; 5) mapped to specific verification event(s); 6) if appropriate, tracked with a TPM for its predicted compliance within allocated resources; 7) decomposed, allocated, and linked to related requirements; 8) assigned a validation method and validation plan cross-reference; and 9) properly represented in trade studies, analysis, and risk assessment.
- h) The Contractor shall support the CEV SRR and develop, deliver and maintain the following documents: in addition to standard products delivered as part of 2.4 Integrated Analysis: **CEV-S-003, System Safety Hazard Analyses, DRD CEV-T-031, CEV Spacecraft System Requirements Specification, DRD CEV-T-032, CEV Specification and Drawing Trees, and DRD CEV-T-034, Requirements Traceability Report**.
- i) The Contractor shall define the modules, subsystems, components, and software units that make up the CEV Spacecraft per the requirements and deliverables included in this section.
- j) The Contractor shall allocate CEV Spacecraft requirements down to the component level for the design of flight articles and maintain the allocations/specifications over the life of the contract.
- k) The Contractor shall document module-level requirements using **DRD CEV-T-031, CEV <Module> Requirements Specifications**. The Contractor shall produce a requirements document for each module.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-031: CEV Spacecraft Requirements Specification
- DRD CEV-T-031: CEV <Module> Requirements Specifications
- DRD CEV-T-032: CEV Specification and Drawing Trees
- DRD CEV-T-033: CEV Architecture Design Document
- DRD CEV-T-034: CEV Requirements Traceability Report

2.3 CEV and Program Integration and Interfaces Management

CEV and Program Integration and Interfaces Management consists of the efforts to integrate the CEV System and integrate the CEV System into the Constellation and International Space Station Programs.

2.3.(a) Constellation Program Integration

- a) The Contractor shall support NASA in the performance of all work necessary to successfully integrate the CEV System into the Constellation Program, as defined by the following documents:
- CXP-70026, Orion to Crew Launch Vehicle (CLV) IRD
 - CXP-70028, Orion to Ground Systems IRD
 - CXP-70029, Orion to Mission Systems IRD
 - CXP-70035, Portable Equipment, Payloads, and Cargo IRD
 - CXP-70033, Orion to Extravehicular Activity (EVA) System IRD
 - CXP-70034, Orion to Lunar Surface Access Module (LSAM) IRD
 - CxP-70118-1 Constellation Program Systems to Communications and Tracking Network Interface Requirements Document, Volume 1: Orion.

Support shall include:

- Coordination of the development, allocation, maintenance, and implementation of integration requirements between the CEV System and other Constellation elements.
 - Development and maintenance of the CEV to other Constellation element External Interface Control Documents per **DRD CEV-T-029, *Interface Control Documents***.
 - Design, development, test, and evaluation of the interfaces between the CEV System and other Constellation Program elements and the integrated performance of the CEV with the other Constellation Program elements for nominal, as well as critical, contingency design cases including abort design cases as appropriate. NASA will provide, aerodynamic and aerothermodynamic analyses for the CEV while mated to its launch vehicle and while unmated. The Contractor shall design the CEV for the resultant induced structural and thermodynamic loads. The Contractor shall use the applicable requirements in Contract Attachment J-3, Table 1.2, Applicable Environmental Data Documents, for loads analysis of the CEV while mated to its launch vehicle.
 - Participation in the Constellation Program and other Project System Reviews. Participation in the requirements reconciliation activities that will occur after the Constellation Program and other Project Reviews.
- b) The Contractor shall perform analyses and tests and provide reports and engineering data supporting integration and operation of CEV and other Constellation elements such as:
- Structural models and analyses for static, dynamic and coupled-loads analyses
 - Mass properties, dimensions and physical (material, thermal, etc.) properties
 - Rendezvous, proximity operations, and abort mode trigger condition and implementation assessments
 - Integrated compatibility analyses (EMC, RF, etc.)
 - Interface and integration drawings and build/test procedures

The reports and engineering data shall be provided in **DRD CEV-T-010, *System Performance Analysis Reports***.

Crew Exploration Vehicle – (CEV)

Modification 904

- c) The Contractor shall perform analyses and support integrated assessments in support of periodic Constellation Program Integration Reviews conducted in conjunction with other NASA elements as described in **DRD CEV-M-001**, *CEV Prime Project Management Plan*.

Deliverables

The Contractor shall deliver and maintain the following(s):

- DRD CEV-T-029: External Interface Control Documents for Constellation Elements
Constellation Program Integration related information is incorporated into the following documents delivered under Section 2.4, Integrated Analysis:
- DRD CEV-T-010: System Performance Analysis Report

2.3.(b) CEV to International Space Station Program Integration

- a) The Contractor shall support NASA in the performance of all work necessary to successfully integrate the CEV System with the ISS Program. Support shall include:
- Coordination of the development, allocation, maintenance, and implementation of integration requirements between the CEV System and the ISS Program.
 - Development and maintenance of the CEV to ISS External Interface Control Documents per **DRD CEV-T-029**, Interface Control Documents.
 - The Contractor shall use CXP-70031, Orion to International Space Station (ISS) IRD to assist in the development of CEV to ISS interfaces.
 - Design, development, test, and evaluation of the interfaces between the CEV and ISS and the integrated performance of the CEV with the ISS for nominal as well as critical contingency design cases.
- b) The Contractor shall perform analyses and tests and provide reports and engineering data supporting integration and operation of CEV and ISS appropriate to such integration, such as:
- Structural models and analyses for static, dynamic and coupled loads analyses
 - Mass properties, dimensions and physical (material, thermal, etc.) properties
 - Rendezvous, proximity operations, and abort trigger condition and implementation assessments
 - Integrated compatibility analyses for all impacted systems
 - Interface and integration drawings and build/test procedures

The reports and engineering data shall be provided in **DRD CEV-T-010**, *System Performance Analysis Reports*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-029: External Interface Control Documents for ISS Elements
ISS Program Integration related information is incorporated into the following documents delivered under Section 2.4, Integrated Analysis:
- DRD CEV-T-010: System Performance Analysis Report

2.3.(c) Spacecraft Integration

Spacecraft Integration incorporates the efforts required to define and manage the internal spacecraft interfaces. Spacecraft Integration includes tasks to perform analyses and provide

Crew Exploration Vehicle – (CEV)

Modification 904

reports and engineering data supporting integration, verification and operation of CEV and provide technical data, and models required to perform integrated CEV level analyses

- a) The Contractor shall develop, maintain, and deliver all drawings and technical Computer Aided Design (CAD) models of the CEV Spacecraft system, modules, subsystems and components.
- b) The Contractor shall develop and maintain models and simulations for the CEV Spacecraft, modules, subsystems, and components using **DRD CEV-T-001**, *Integrated Models, Simulations and Support Plan*, and **DRD CEV-T-002**, *CEV Engineering Models*.
- c) The Contractor shall document and maintain interface requirements using **DRD CEV-T-035**, *Internal Interface Requirement Document (IRD)*. The Contractor shall produce an IRD for each module that interfaces with another module.
- d) The Contractor shall perform the system integration effort required to manage and control the internal spacecraft interface definition process.
- e) The Contractor shall perform analyses required to validate the allocation of requirements and shall document the results in **DRD CEV-T-010**, *System Performance Analysis Report*.
- f) The Contractor shall document all internal interface design details using **DRD CEV-T-029**, *CEV Interface Control Documents*. The Contractor shall produce an ICD (CEV-T-029) for each Module that interfaces with another Module.
- g) The Contractor shall develop and maintain the overall vehicle system design which ensures all subsystems are integrated into the vehicle and that the total vehicle performance closes in compliance with the system requirements. The Contractor shall include NASA personnel on all design teams established by the Contractor.
- h) The Contractor shall design and develop the spacecraft in compliance with the NASA provided and maintained CxP-72085, Crew Exploration Vehicle (CEV) Spacecraft Outer Mold Line (OML), and Center of Gravity (Cg) box definition. The Contractor shall submit changes to NASA against the Spacecraft OML baseline to accommodate maturing design features.
- i) The Contractor shall design and develop the spacecraft in compliance with the NASA CxP-72167, Orion Aerodynamic Database, CxP-72168, Orion Aerothermodynamic Database.
- j) NASA will provide the following products to the Contractor:
 - o CxP-72085, Crew Exploration Vehicle (CEV) Spacecraft Outer Mold Line (OML)
 - o CxP-72167, Orion Aerodynamic Database (for all phases of flight)
 - o CxP-72168, Orion Aerothermodynamic Database (for all phases of flight)
 - o CEV Spacecraft docking components (Androgynous Peripheral Assembly System (APAS) and Low Impact Docking System (LIDS)) of the docking system for ISS and LSAM docking requirements
 - o Parachute system in support of nominal and abort entries (see Landing & Recovery Systems, section 6.1.3.14.) **with exception of** pyrotechnic devices excluding pyrotechnic reefing line cutters in accordance with Attachment J-9 Deliverable Items List.
 - o Suit Vehicle Multiuse Connector
 - o Pyrotechnics initiators
 - o CEV to ISS Docking Adapter
 - o ISS C3I Communications Adapter (ICCA)
 - o Active and passive radiation instrumentation

All Government Furnished Equipment (GFE) product teams will produce data deliverables equivalent to the contractor furnished equipment product data deliverables.

- k) The Contractor shall integrate the NASA-provided products into the spacecraft design and flight configurations to ensure that the integrated spacecraft meets CXP-72000, Systems Requirements for the Crew Exploration Vehicle Element (CEV SRD). The Contractor shall

Crew Exploration Vehicle – (CEV)

Modification 904

integrate the NASA-provided products and documentation into applicable product deliverables included in this SOW (these include requirements, drawings, certification packages, integrated analyses, and the spacecraft).

- l) NASA will maintain detailed oversight of all spacecraft design activities. The Contractor shall maintain responsibility for delivery of a design that meets the requirements. The detailed process discussion to accomplish this can be found in CxP-72008, Crew Exploration Vehicle Project Plan. The Contractor shall include NASA personnel on all design teams established by the Contractor.
- m) The Contractor shall allocate requirements to the following government furnished products:
 - o CEV Spacecraft docking components (APAS and LIDS) of the docking system for ISS and LSAM docking requirements
 - o Parachute system in support of nominal and abort entries
 - o Pyrotechnics initiators
- n) The Contractor shall ensure that traceability between the levels is in accordance with the capability established in Section 2.2, Requirements Definition and Management.
- o) The Contractor shall use the following standards for developing all subsystems:
 - o AIAA-S-080, AIAA Standard for Space Systems – Metallic Pressure Vessels Pressurized Structures, and Pressure Components
 - o ANSI/AIAA-S-081A-2006, AIAA Standard for Space Systems – Composite Overwrapped Pressure Vessels
- p) The Contractor shall develop and maintain the ISS Resident RF equipment to ICCA Interface Control Document in accordance with DRD CEV-T-029 Interface Control Documents.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-029: <Module-Module> Internal Interface Control Documents
- DRD CEV-T-029: Internal Interface Control Document for ISS Resident RF Equipment to ICCA
- DRD CEV-T-035: Internal Interface Requirements Document (for each Module that interfaces with another Module)

Spacecraft Integration related information is incorporated into the following documents delivered under Section 2.4, Integrated Analysis:

- DRD CEV-T-001: Integrated Models, Simulations, and Support Plan
- DRD CEV-T-002: CEV Engineering Models
- DRD CEV-T-010: System Performance Analysis Report

2.4 Integrated Analysis

Integrated Analysis includes Systems Engineering and Integration Analysis activities to provide consistency across all aspects of the CEV System development efforts. This element includes the work to identify and conduct trade studies and cost-effectiveness analyses across the CEV System and the overall Constellation Program Architecture. It includes efforts to develop design and analysis tools, and models and simulations. It also includes tasks to define, control and verify CEV mass properties and other controlled technical margins across the CEV vehicle.

- a) The Contractor shall manage crosscutting engineering issues within the spacecraft, such as the allocation of resources into the design elements including the management of margins and design and operational performance estimates for various modules and below. This information shall be documented in **DRD CEV-T-036, Margins Management Plan/Report**, and implemented by the Contractor.

Crew Exploration Vehicle – (CEV)

Modification 904

- b) The Contractor shall perform analyses required to validate the allocation of requirements and shall document the results in **DRD CEV-T-010**, *System Performance Analysis Report*.
- c) The Contractor shall identify and conduct trade studies and cost-effectiveness analyses to ensure realistic options and alternatives are assessed for key CEV System requirements and design decisions. The assessment of cost shall address all elements of life cycle cost significantly affected by the matters being traded.
- d) The Contractor shall develop and implement a CEV System Analysis Plan. The Contractor shall deliver the analysis plan per **DRD CEV-T-008**, *CEV System Analysis Plan*. The Contractor shall include the relationship of all analysis cycles and their products to the major milestones, events, etc. they are to support in the Integrated Master Schedule as part of **DRD CEV-B-003**, *Cost Performance Report*. The Contractor shall report results of the analysis performed per **DRD CEV-T-009**, *CEV Analysis Reports*.
- e) The Contractor shall perform an integrated system performance analysis and provide reports in accordance with **DRD CEV-T-010**, *System Performance Analysis Report* at major milestone reviews and at intervals prescribed in CxP-72008, Crew Exploration Vehicle Project Plan.
- f) The Contractor shall provide the analysis to validate all CEV System requirements through the lowest level of decomposition and document the validation per **DRD CEV-T-009**, *CEV Analysis Reports*.
- g) The Contractor shall provide/receive various mathematical models, configuration data, and analytical data necessary to perform integrated assessments and analysis to integrate with the Constellation Program.
- h) The Contractor shall provide/receive various mathematical models, configuration data, and analytical data necessary to perform integrated assessments and analysis to integrate with the ISS Program.
- i) The Contractor shall define a plan for managing mass properties and document this plan in **DRD CEV-T-042**, *Mass Properties Control Plan*. The Contractor shall implement this plan and document the results in **DRD CEV-T-043**, *Mass Properties Reports*.
- j) The Contractor shall develop, implement, deliver and maintain a Modeling and Simulation Support Plan in accordance with **DRD CEV-T-001**, *Integrated Models, Simulations and Support Plan*.
- k) The Contractor shall deliver and maintain models supporting discipline-oriented engineering analysis and trade studies in accordance with **DRD CEV-T-002**, *CEV Engineering Models*. These models shall be consistent with the coordinate system described in CxP 70138, Constellation Program Level 2 Coordinate Systems.
- l) The Contractor shall deliver and maintain a system architecture model and discrete-event simulation to evaluate effectiveness and performance of the vehicle design in accordance with **DRD CEV-T-001**, *Integrated Models, Simulations and Support Plan*.
- m) The Contractor shall deliver and maintain modular, high-fidelity, time-stepped simulations of vehicle behavior for avionics hardware and software integration and test in accordance with the IEEE 1516.3-2000 (High Level Architecture) standard and **DRD CEV-T-001**, *Integrated Models, Simulations and Support Plan*.
- n) The Contractor shall make available to NASA all Contractor-developed design and analysis tools, models and simulations used in the development of the CEV System, including source-code and geographic models/block diagrams from Computer Aided Software Engineering Tools, in accordance with the Electronic Data Access Clause (H.12).
- o) Every tool, model, and simulation delivery shall be accompanied by a meta-data document in accordance with CXP-70041, Constellation Program NExIOM Standard for Tool, Model and Simulation Deliveries.

Crew Exploration Vehicle – (CEV)

Modification 904

- p) The Contractor shall provide the configuration management data for all technical models and drawings to the NASA ICE per **DRD CEV-M-003**, *Configuration Management Plan and Reports*.
- q) The Contractor shall deliver all CAD models per **DRD CEV-T-003**, *CEV CAD Models*, and drawings per **DRD CEV-T-004**, *CEV Drawings*.
- r) The Contractor shall participate in the Verification, Validation and Accreditation process described in CXP-70076; Constellation Program Modeling and Simulation Management Requirements.
- s) If the Contractor utilizes modeling and simulation to conduct analysis in support of verification specification compliance, the Contractor shall comply with **DRD CEV-T-001**, *Integrated Models, Simulations and Support Plan*, and **DRD CEV-T-002**, *CEV Engineering Models*.
- t) NASA will develop drawings and CAD models for all GFE. NASA will use **DRD CEV-T-003**, *CEV CAD Models*, and **DRD CEV-T-004**, *CEV Drawings*, as the template for development and delivery of these items.
- u) NASA will develop models and simulations for all GFE. NASA will use **DRD CEV-T-001**, *Integrated Models, Simulations and Support Plan*, and **DRD CEV-T-002**, *CEV Engineering Models*, as the template for development and delivery of these items.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-001: Integrated Models, Simulations and Support Plan
- DRD CEV-T-002: CEV Engineering Models
- DRD CEV-T-003: CEV CAD Models
- DRD CEV-T-004: CEV Drawings
- DRD CEV-T-008: CEV System Analysis Plan
- DRD CEV-T-009: CEV Analysis Reports
- DRD CEV-T-010: System Performance Analysis Report
- DRD CEV-T-036: Margins Management Plan/Report
- DRD CEV-T-042: Mass Properties Control Plan
- DRD CEV-T-043: Mass Properties Reports

2.5 Spacecraft Crew Cabin and Cockpit Layout Design Requirements

- a) NASA and the Contractor shall jointly participate in the development of detailed design requirements for the CEV crew cabin, and cockpit layout and functionality.
- b) Reserved
- c) Reserved
- d) The Contractor shall provide materials (e.g., layout schematics, computer 3-D models) for two Crew Station Reviews. The Contractor shall conduct these two Crew Station Reviews between System PDR and System CDR of the Contractor's CEV crew cabin internal layout design utilizing NASA-identified Crew Office representatives. After each Crew Station Review, the Contractor shall prepare and provide to NASA an impact assessment of quantifiable design issues arising from each review.
- e) NASA will document the display format standards in CxP 72242, CEV Display Format Standards Document.
- f) NASA and the Contractor shall jointly participate in prototyping the layout and behavior of the display formats, using CxP 72242, CEV Display Format Standards Document as an

Crew Exploration Vehicle – (CEV)

Modification 904

applicable document. The Contractor shall develop and maintain a Display Format Dictionary in accordance with DRD CEV-T-048, Software Requirement Specification. The Display Format Dictionary shall document the results of the prototyping effort.

- g) The Contractor shall develop and maintain DRD CEV-T-048, Display & Control Software Requirements Specification appendix for the Display Format Dictionary.
- h) The contractor shall provide supplemental rapid-prototyping tool operators to augment the NASA provided tool-operators. The tool operators will provide associated stub models to exercise the prototype display formats. (IDIQ)
- i)

2.6 CEV Systems Integration Management

CEV Systems Integration Management consists of the discipline-specific efforts to manage the overall integrated CEV system architecture definition and engineering functions including the interfaces with external Constellation Systems. This includes the technical and management efforts of directing and controlling the integrated engineering effort for the CEV spacecraft in all modes and configurations.

Systems Integration Management consists of the efforts to manage the Contractor's systems integration activities and to manage the Contractor's participation in NASA-led Constellation Program systems integration activities in accordance with NASA requirements and the Contractor's documented plans.

- a) The Contractor shall manage their systems integration activities consistent with CxP-72008, Crew Exploration Vehicle Project Plan.
- b) The Contractor shall participate in CEV Project and Constellation Program systems integration activities in accordance with CxP-72008, Crew Exploration Vehicle Project Plan.
- c) The Contractor shall implement plans for managing technical data products, processes and organizational roles and responsibilities used to accomplish their systems integration activities and document their plans in the Contractor's PMP (DRD CEV-M-001, CEV Prime Project Management Plan).
- d) The Contractor shall perform requirements development, design, analysis and trade studies, assembly/production, integration, testing, verification, validation, qualification, certification, and delivery for all CEV Spacecraft subsystems to the component level. A small number of subsystems contain government furnished products. These NASA-provided products will be detailed in each subsystem section.
- e) The Contractor shall hold subsystem design reviews prior to the system PDR and CDR.
- f) The Contractor shall perform analyses, trade studies, and developmental testing to determine the spacecraft architecture and component design that meets all requirements and best balances performance, cost, schedule, and risk. The Contractor shall document this design information in each of the subsystem design and data books.
- g) The Contractor shall demonstrate how the design maps to and complies with the CEV System-level and external interface requirements. The Contractor shall document this requirements mapping in **DRD CEV-T-034, Requirements Traceability Report**.
- h) The Contractor shall support the documentation and delivery of the *Master Verification Plan* (DRD CEV-T-015). The Contractor shall document this information at the CEV Spacecraft system, module, subsystem, and component levels in the Spacecraft Master Verification Plan.
- i) The Contractor shall specify, produce and deliver integration testing assemblies and flight test articles necessary to implement the Spacecraft Master Verification Plan. The Contractor

Crew Exploration Vehicle – (CEV)

Modification 904

shall document this information at the CEV Spacecraft system, module, subsystem, and component levels in **DRD CEV-T-017, Certification Data Package**. Note: Module, subsystem and component-level test and test documentation requirements are defined in Sections 6.1.5 CM Test, Verification, and Certification, 6.2.5 SM Test, Verification, and Certification, 6.4.5 LAS Test, Verification, and Certification and 6.5.4 CEV Software Test and Verification. The contractor shall deliver Certification Approval Requests per **DRD CEV-T-018** in preparation for design certification milestones.

- j) The Contractor shall perform acceptance testing at the integrated spacecraft level using **DRD CEV-T-039, Acceptance Test Procedures**, and document the results using **DRD CEV-T-040, Acceptance Data Package**.
- k) NASA has identified subsystem-specific standards the Contractor shall follow during all design, development, and test activities. The standards are listed in Subsection sections within Sections 6.1.3 (CM Subsystems), 6.2.3 (SM/SA Subsystems) and 6.4.3 (LAS Subsystems). Crosscutting standards applying to all subsystems are covered in Section 2.8, Specialty Engineering, sections 2.9 (Aerosciences), and 2.4 (Integrated Analysis).
- l) The Contractor shall use the following standards and requirements documents for developing all subsystems:
 - o JPR 8080.5, JSC Design and Procedural Standards (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List) (exclusive of government "shall")
 - o CXP-70024, Constellation Human Systems Integration Requirements (HSIR) (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List)

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-034: Requirements Traceability Report

The following DRDs for the integrated vehicle are collected in the DRDs specified in Section 10.

- DRD CEV-T-015: Master Verification Plan
- DRD CEV-T-017 Certification Data Packages
- DRD CEV-T-018: Certification Approval Request
- DRD CEV-T-039: Acceptance Test Procedures
- DRD CEV-T-040: Acceptance Data Package

2.6.1 Avionics Integration

The contractor shall integrate the efforts to design, develop, test, certify, and deliver the software, computers, firmware, and other electrical and electronic equipment used for commanding, monitoring, and communicating with CEV subsystems.

Avionics Integration includes the integration of the hardware and software components in the areas of Flight Software, Command & Data Handling (C&DH), Instrumentation, Communications and Tracking (C&T), Displays & Controls (D&C), and all data/signal interfaces between these functions and other CEV Spacecraft systems/modules/subsystems/components and external elements. This element also includes efforts to develop and implement an approach for modular open systems architecture in the design of the CEV System, and to define the collection and processing of vehicle transducer and sensor information and vehicle health monitoring data specified by other subsystems for use on the vehicle and ground.

Crew Exploration Vehicle – (CEV)

Modification 904

- a) The Contractor shall use a modular, multi-use open systems approach in the design of the CEV System making the impact to the overall modular, multi-use open systems architecture a primary consideration in the selection of equipment to meet the CEV design functionality. This approach shall be reflected in the architecture documented in the *Architecture Design Document* (**DRD CEV-T-033**).
- b) The Contractor shall use a modular, multi-use open systems approach and analysis of long-term supportability, interoperability, and growth for future modifications in the final selection of CEV equipment and the integration approach for future Constellation elements and equipment.
- c) The Contractor's design shall permit future upgrades and incremental technology insertion to allow for incorporation of additional or higher performance components with minimal impact to the existing systems.
- d) The Contractor shall report the results of an open systems architecture analysis for modular, multi-use systems that extends beyond CEV to other Constellation elements and equipment in accordance with **DRD CEV-T-009**, *CEV Analysis Reports*.
- e) NASA will perform independent requirements validation and design certification in key areas. In these key areas NASA will establish design requirements teams intended to integrate the activities of NASA and the Contractor. The Contractor shall participate in and support these design requirements teams for CEV Avionics Integration Laboratory Requirements.
- f) The Contractor shall define and implement an integrated plan for CEV Spacecraft instrumentation. The Contractor shall provide in this plan provisions for the calibration of the instrumentation transducers and sensors to assure end-to-end error and tolerances are within required performance specifications. The Contractor shall document these plans in **DRD CEV-T-041**, *CEV Instrumentation Plan*.
- g) The Contractor shall define and document sensor range and calibration information in **DRD CEV-T-046**, *CEV Data and Command Dictionary*, using the standards and formats called out in CxP 70022-4 Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Books, Volume 4: Information Representation Specification (and associated children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List).
- h) The Contractor shall develop, implement, and maintain an Integrated Avionics Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of the avionics system.
- i) The Contractor shall perform certification testing of the avionics subsystem and document the results using **DRD CEV-T-017**, *Certification Data Package*.
- j) The Contractor shall develop and maintain a sortable *CEV Data and Command Dictionary* (**DRD CEV-T-046**), which includes channelization information, calibration information, telemetry information, and command information required to define, manage and record all data elements that interface with the core avionics software and hardware, the subsystem specific software, and the ground systems, using the standards and formats called out in CxP 70022-4 Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Books, Volume 4: Information Representation Specification (and associated
- k) The Contractor shall develop an Avionics Subsystem - Constellation C3I Interoperability Report (also see section 6.5.2) per **DRD CEV-T-047**, *Avionics Design and Data Book Volume V - Avionics Subsystem - Constellation C3I Interoperability Report*, to detail how the Contractor's design will adhere to CXP-70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volumes 1, 2, 3, 4, 5 and 8 (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List).

Crew Exploration Vehicle – (CEV)

Modification 904

- l) The Contractor shall develop **DRD CEV-T-047, Avionics Design and Data Book Volume I - Avionics System-Level Data**, which contains avionics architecture diagrams, results of trade studies and performance analyses, block diagrams, schematics, prototyping results, design data, planned growth provisions/margins/scarring, and discussion of fault tolerance and effects of failures on performance.
- m) The Contractor shall utilize open architecture designs and industry standards where feasible and cost-effective in the avionics subsystem hardware and software designs, taking into consideration long-term maintainability/availability and extensibility. The Contractor shall utilize modular hardware and common building blocks such as power supplies, chassis, processor cards, memory cards, network cards, etc. where feasible and cost-effective.
- n) The Contractor shall utilize standard compilers, operating systems, and software development tools/environments throughout the CEV software design and development process where feasible and cost-effective.
- o) Reserved
- p) For each avionics LRU that requires active cooling, the Contractor shall determine the maximum time that the LRU can be operated without active cooling applied. The Contractor shall document this data in each volume of the avionic design and data book.
- q) The Contractor shall use the following standards for designing the avionics subsystem:

CxP 70022-1 Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Books, Volume 1: Interoperability Specification (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List)

CxP 70022-2 Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Books, Volume 2: Spectrum and Channel Plan

CxP 70022-3 Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Books, Volume 3: Master Link Book

CxP 70022-4 Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Books, Volume 4: Information Representation Specification (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List)

CxP 70022-5 Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Books, Volume 5: Data Exchange Protocol Specification

CxP 70022-8 Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Books, Volume 8: Common Command and Control Functional Requirements (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List)

- r) The Contractor shall design, develop, produce, integrate, verify, validate, certify, operate, maintain, document, and deliver a separate backup flight control system (BFCS), which houses an independently developed subset of the primary flight software functions.
- s) The Contractor shall design, develop, produce, integrate, verify, validate, certify, operate, maintain, document, and deliver an avionics architecture based on fifth generation

Crew Exploration Vehicle – (CEV)

Modification 904

commercial aircraft heritage, that is of a high (greater than 6) technology readiness level (TRL).

- t) The Contractor shall lead the integration of the integrated resident RF communications hardware and the GFE provided ISS C3I Communications Adapter (ICCA), with the ISS.
- u) The Contractor shall develop an Avionics Subsystem - Constellation Functional Security Report per **DRD CEV-T-047**, *Avionics Design and Data Book Volume VI - Avionics Subsystem - Constellation Security Report*, to detail how the Contractor's design will adhere to CxP 70070-ANX05, Book 1, Constellation Program Functional Security Requirements (and associated children).
- v) The Contractor shall develop and maintain **DRD-CEV-T-031**, *CEV <Subsystem> Requirements Specification* for the Avionics Subsystem
- w) The Contractor shall develop and maintain **DRD CEV-T-029**, *CEV <Subsystem> Interface Control Documents* and **DRD CEV-T-035**, *CEV <Subsystem> Interface Requirements Documents* for the Avionics Subsystem interfaces to other subsystems.
- x) The Contractor shall document the Avionics subsystem requirements traceability in **DRD CEV-T-034**, *Requirements Traceability Report*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD-CEV-T-015: Integrated Avionics Volume Master Verification Plan (excluding GN&C)
- DRD-CEV-T-029: Avionics Subsystem Interface Control Documents
- DRD-CEV-T-031: Avionics Subsystem Requirements Specification
- DRD-CEV-T-035: Avionics Subsystem Interface Requirements Documents
- DRD CEV-T-041: CEV Instrumentation Plan
- DRD CEV-T-046: CEV Data and Command Dictionary
- DRD CEV-T-047: Avionics Design and Data Book Volume 1 Avionics, System-Level Data
- DRD CEV-T-047: Avionics Design and Data Book Volume VI, Avionics Subsystem-Constellation Security Report

The following subsystem specific data is collected in the DRDs specified in Section 2.2:

- DRD CEV-T-033: Architecture Design Document
- DRD CEV-T-034: Requirements Traceability Report

The following subsystem specific data is collected in the DRDs specified in Section 2.4:

- DRD CEV-T-009: CEV Analysis Reports

The following subsystem specific information is collected in the DRDs specified in Section 6.5.2:

- DRD CEV-T-047: Avionics Design and Data Book Volume V, Avionics – Constellation C3I Interoperability Report

The following subsystem specific data is collected in the DRDs specified in Sections 10.2:

- DRD CEV-T-017: Certification Data Package

2.6.2 Command and Data Handling (C&DH) Integration

C&DH hardware includes data processing and computing resources including processors, memory, input/output devices, data multiplexers/ demultiplexers, mass storage devices, inter-computer time-synchronization devices, and networking equipment

- (a) The contractor shall integrate the DDT&E efforts of the C&DH hardware.

Crew Exploration Vehicle – (CEV)

Modification 904

- (b) The Contractor shall document the design integration for all C&DH hardware as specified in **DRD CEV-T-047**, *Avionics Design and Data Book Volume II - C&DH/Instrumentation Subsystem Data*.
- (c) The Contractor shall participate with NASA in the integration of CEV hard-line interface to the GFE ICCA onboard ISS.
- (d) The Contractor shall develop and maintain **DRD CEV-T-031**, CEV <Components> Requirements Specifications for the C&DH components.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-031: Command and Data Handling Component Requirements Specifications
- DRD CEV-T-047: Avionics Design and Data Book Volume II C&DH/Instrumentation Subsystem Data

2.6.3 Communications and Tracking

The Contractor shall integrate the DDT&E efforts of the space-to-ground and space-to-space communication links, RF/optical tracking devices (excluding navigational aids), audio and video/imagery equipment and ISS resident RF communications hardware including hardware to be installed on the ISS.

- (a) The Contractor shall prepare, deliver, and maintain **DRD CEV-T-047**, *Avionics Design and Data Book Volume III - Communications and Tracking Subsystem Data*.
- (b) The Contractor shall participate in the development of Constellation's integrated communications and tracking concepts, architecture, and requirements. The Contractor shall comply with the design of the Constellation communications architecture according to CXP-70022 Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Books Volumes 1, 2, 3, 4, 5 and 8 (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List).
- (c) Subsystems other than C&T may contain RF/optical devices (i.e., wireless sensors, GPS). The Contractor shall apply the standards in this section to those subsystems containing RF/optical devices. The Contractor shall provide the same documentation required in **DRD CEV-T-047**, *Avionics Design and Data Book Volume III - Communications and Tracking Subsystem Data*, for all subsystems containing RF/optical devices. The Contractor shall document this information in that subsystems design and data book.
- (d) The Contractor shall participate in the development of Radio Frequency/Optical ICDs and document the results in **DRD CEV-T-058**, *Radio Frequency/Optical ICDs*.
- (e) The Contractor shall use the following standards for designing the C&T subsystem:
 - 450-SNUG, Space Network Users' Guide
 - FIPS 140-2, Security Requirements for Cryptographic Module
 - FIPS-197, Advanced Encryption Standard
 - ICD-GPS-200, Navstar GPS Space Segment/Navigation User Interfaces
 - NTIA Manual, National Telecommunications and Information Administration (NTIA) Manual of Regulations & Procedures for Federal Radio Frequency Management (May 2003 Edition, May 2005 Revisions) Chapter 10
- (f) The Contractor shall design, develop, produce, integrate, verify, validate, certify, operate, maintain, document, and deliver ISS resident RF communications hardware (antenna, amplifiers, transponders, baseband processing, and other associated hardware).

Crew Exploration Vehicle – (CEV)

Modification 994

- g) The Contractor shall integrate the resident RF communications hardware with the GFE provided ISS C3I Communications Adapter (ICCA).
- h) The CEV Contractor shall participate with NASA and the Constellation Program in development of Radio Frequency (RF) spectrum management in compliance with the National Telecommunications and Information Administration (NTIA) Manual of Regulations & Procedures for Federal Radio Frequency Management (May 2003 Edition, May 2005 Revisions), Chapter 10. The Contractor shall provide RF spectrum management documentation in **DRD CEV-T-026**, Spectrum Management Documents
- i) The Contractor shall develop and maintain **DRD CEV-T-031**, CEV <Components> Requirements Specifications for the C&T components.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-026, Spectrum Management Documents
- DRD CEV-T-031: Communication & Tracking Components Requirements Specifications
- DRD CEV-T-047: Avionics Design and Data Book Volume III – Communications and Tracking Subsystem Data
- DRD CEV-T-058: Radio Frequency/Optical ICDs

2.6.4 Displays & Controls Integration

The contractor shall integrate the DDT&E efforts of the crew interface with the on-board computer systems and the manual controls/feedbacks used by the crew to control the vehicle, interact with its subsystems, and monitor automated processes. This work is done in concert with Human Engineering activities under Section 2.8, Specialty Engineering, and 2.5, Spacecraft Crew Cabin and Cockpit Layout Design Requirements.

- a) Reserved
- b) The D&C subsystem shall utilize naming conventions as established in CXP-02007, Constellation Nomenclature Plan.
- c) The Contractor shall prepare, maintain, and deliver Avionics Design and Data Book Volume IV - Displays and Controls Subsystem Data per **DRD CEV-T-047**.
- d) The Contractor shall develop and maintain **DRD CEV-T-031**, CEV <Components> Requirements Specifications for the Displays and Controls components.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-031: Displays & Controls Components Requirements Specifications
- DRD CEV-T-047: Avionics Design and Data Book Volume IV – Displays and Controls Subsystem Data

2.6.5 Electrical Power Subsystem (EPS) Integration

The contractor shall integrate the DDT&E efforts of the power generation, energy storage, electrical power distribution and control, and external/internal CEV lighting.

- a) The Contractor shall participate with the Constellation Program in the development of **DRD CEV-T-060**, *Electrical Power Quality Specification Requirements Document*. The Contractor

Crew Exploration Vehicle – (CEV)

Modification 904

shall perform testing and analyses required to develop a power quality specification that will be compatible with the technology needed to generate, store, and distribute electrical power. The Constellation Program will provide oversight and guidance with an emphasis to tailor this specification to be compatible to both the CEV and other similar Constellation EPS systems.

- b) The Contractor shall document the design for the Electrical Power Subsystem as specified in **DRD CEV-T-059, *Electrical Power System (EPS) Design and Data Book***
- c) The Contractor shall develop, implement, and maintain an Integrated EPS Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of the EPS system.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-059: Electrical Power System (EPS) Design and Data Book
- DRD CEV-T-060: Electrical Power Quality Specification Requirements Document

The following subsystem specific information is collected in the DRDs specified in Section 10.2

- DRD CEV-T-015: EPS Volume - Master Verification Plan

2.6.6 Mechanisms Integration

The Contractor shall integrate the DDT&E efforts of any mechanical or electromechanical devices that control the movement of a mechanical part of the spacecraft relative to another part. These devices include latches, hatches, doors, and fasteners installed, removed, or adjusted during flight.

- a) The Contractor shall design develop, and verify safety or mission critical mechanisms in accordance with the following standard:
 - NASA-STD-5017, Design and Development Requirements for Mechanisms, Sections 1-4
- b) The Contractor shall document the design for all CEV mechanisms as specified in **DRD CEV-T-061**, Mechanical Systems Design and Data Book, and **DRD CEV-T-062**: Stress Analysis Report.
- c) The Contractor shall develop, implement, and maintain an Integrated Mechanisms Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of the Mechanisms system.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-061: Mechanical Systems Design and Data Book
- DRD CEV-T-062: Stress Analysis Report

The following subsystem specific information is collected in the DRDs specified in Section 10.2

- DRD CEV-T-015: Mechanisms Volume - Master Verification Plan

2.6.7 Passive Thermal Control Integration

The Contractor shall integrate the DDT&E efforts of hardware, coatings, blankets, heaters, and other design accommodations that protect the vehicle, crew, and its constituent components from thermal environmental extremes during all mission phases.

- a) The Contractor shall develop thermal analytical models to support integrated Constellation vehicle analyses and CEV thermal analyses.
- b) The Contractor shall develop, implement, and maintain an Passive Thermal Control Subsystem Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of the PTC system.
- c) The Contractor shall document the design for the Passive Thermal Control subsystem as specified in **DRD CEV-T-063**, Passive Thermal Control Design and Data Book.
- d) The contractor shall deliver **DRD CEV-T-064**, *Passive Thermal Control Mathematical Models and Documentation*, which will edliver and describe the mathematical models used in the PTC analyses.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-063: Passive Thermal Control Design and Data Book (PTCDDDB)
- DRD CEV-T-064: Passive Thermal Control Mathematical Models and Documentation

The following subsystem specific information is collected in the DRDs specified in Section 10.2

- DRD CEV-T-015: PTC Volume - Master Verification Plan

2.6.8 Reserved

2.6.9 Structures Integration

The Contractor shall integrate the DDT&E efforts of the primary structure, secondary structure, and all structural components of vehicle equipment, including spacecraft and component loads, dynamics, and stress analysis.

- a) The Contractor shall perform structural analysis on all spacecraft structures, including pressure vessels, to show that all elements of the design such as the strength, stiffness, structural stability, and life meet all specified criteria for the anticipated loads and environments
- b) The Contractor shall perform loads and dynamics analyses and document the results in **DRD CEV-T-067**, *Structural Loads Data Book*.
- c) The Contractor shall perform stress and fatigue analyses and document the results in **DRD CEV-T-062**, *Stress Analysis Report*.
- d) The Contractor shall develop models to support integrated Constellation vehicle analyses as well as CEV loads and stress analyses. The Contractor shall deliver **DRD CEV-T-068**, *Structures Mathematical Models and Documentation*, which will deliver and describe the mathematical models used in the CEV Spacecraft system, module, subsystem, and component loads and stress analyses.
- e) The Contractor shall implement a fracture control program and identify fracture critical parts to protect against catastrophic structural hazards associated with flaw presence, fatigue crack

Crew Exploration Vehicle – (CEV)

Modification 904

propagation and fracture. The Contractor shall deliver and implement **DRD CEV-T-069**, *Fracture Control Plan*, and **DRD CEV-T-070**, *Fracture Control Summary Report*.

- f) The Contractor shall use NASA-HDBK-7005, Dynamic Environmental Criteria, as a guidance document to support the **DRD CEV-T-015**, *Master Verification Plan* DRD product development activity.
- g) The Contractor shall use the following standards for designing and analyzing the structures subsystem:
 - o Contract Attachment J-3, Table 1.2, Applicable Environmental Data Documents
 - o JSC-62550, Structural Design and Verification Criteria for Glass, Ceramics and Windows in Human Space Flight Applications
 - o NASA-STD-5001, Structural Design and Test Factors of Safety for Space Flight Hardware
 - o NASA-STD-5019, Fracture Control Requirements for Spaceflight Hardware as implemented by CEV-T-069
 - o NSTS 08307, Space Shuttle Criteria for Preloaded Bolts
 - o CxP-70135, Structural Design and Verification Requirements (SDVR)
- h) The contractor shall produce an engineering development Ground Test Article (GTA) for use in environmental testing. The contractor shall perform environmental testing on the engineering development structure including, as a minimum, modal testing, vibration testing, and acoustic testing. The contractor shall include the engineering development structure testing activity as part of the **DRD CEV-T-015**, *Master Verification Plan*, and shall ensure that the testing is completed in time to support component qualification testing. The contractor shall document the results of the engineering development structure testing in **DRD CEV-T-067**, *Structural Loads Data Book*, and **DRD CEV-T-068**, *Structures Mathematical Models and Documentation*.
- i) The Contractor shall deliver a CEV Structural Test Article (used for structural verification static and dynamic testing) after the Contractor completes the structural test program.
- j) The Contractor shall support Integrated Vehicle Ground Vibration Test (IVGVT) at MSFC as defined in the Ares IVGVT & Orion Bilateral Exchange Agreement (BEA).
- k) The ISS CCA will be hard mounted on a contractor provided isolation system for launch on Progress.
- l) The Contractor shall develop, implement, and maintain a Structures Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of the Structures system.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-062: Stress Analysis Report
- DRD CEV-T-067: Structural Loads Data Book
- DRD CEV-T-068: Structures Mathematical Models and Documentation
- DRD CEV-T-069: Fracture Control Plan
- DRD CEV-T-070: Fracture Control Summary Report
- Property transfer of Structural Test Article and Ground Test Article residual components
- DD250 of IVGVT test article

The following subsystem specific data is collected in the DRD specified in Sections 10.2:

- DRD CEV-T-015: Master Verification Plan

2.6.10 Propulsion Integration

The Contractor shall integrate the DDT&E efforts of vehicle components that provide propulsive thrust used for trajectory insertion, orbital maneuvering, and translation and rotation reaction control.

- a) The Contractor shall perform design, development, test, certification and delivery of all propulsion systems and develop all propulsion related DRD products.
- b) The Contractor shall develop, document, implement, and execute comprehensive verification activities and associated processes for all propulsion systems in order to certify the propulsion systems for compliance with CEV component, subsystem, module, Spacecraft system, and vehicle-level requirements. The Contractor shall also design, fabricate and test integrated propulsion systems in order to evaluate and certify integrated propulsion system hot fire performance for each propulsion application. The Contractor shall also design, fabricate, and test integrated propulsion systems to evaluate and certify integrated propellant system storage and conditioning designs and capabilities in order to evaluate and certify propellant conditioning performances. The Contractor shall design and certify liquid propellant rocket engines for combustion stability, using CPIA 655, Guidelines for Combustion Stability Specifications and Verification Procedures for Liquid Propellant Rocket Engines.
- c) The Contractor shall develop, implement, and maintain a Propulsion Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of the Propulsion system.
- d) The Contractor shall document the design for the Propulsion subsystem as specified in **DRD CEV-T-071**, Propulsion Systems Design and Data Book.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-071: Propulsion Systems Design and Data Book

The following subsystem specific information is collected in the DRDs specified in Section 10.2

- DRD CEV-T-015: Propulsion Systems Volume - Master Verification Plan

2.6.11 Suits, EVA and Survival Crew Equipment Support Systems Integration

- a) The Contractor shall integrate the DDT&E efforts of components that interface to Suits, EVA and Survival Crew Equipment Support Systems.
- b) NASA will provide the CEV suits and EVA support equipment (e.g., EVA suits, launch and entry suits, helmets, gloves, undergarments, and standard EVA tools if applicable).
- c) NASA will provide crew equipment systems and gear for emergency egress and survival, crew/personnel post landing tracking systems, and crew/personnel post landing communications systems.
- d) The Contractor shall perform requirements development, design, analysis and trade studies, assembly/production, integration, testing, verification, validation, qualification, certification, and delivery of the CEV interfaces for the NASA-provided suits, EVA support equipment, and survival crew equipment.
- e) The Contractor shall supply the vehicle resources to the NASA-provided suits with power, oxygen, water, cooling, contaminant control and communications as defined in the CXP-

Crew Exploration Vehicle – (CEV)

Modification 904

70033, Orion to EVA Systems IRD. The Contractor shall control/provide/analyze the vehicle side interface, and NASA will control/provide the umbilical/support systems hardware and the suit-side interface.

- e) The Contractor shall supply vehicle resources and interfaces for vehicle depressurization/re-pressurization as defined in support of an EVA.
- f) The Contractor shall provide an IVA/EVA-operable CEV Spacecraft hatch and mechanisms, specialized CEV-specific EVA tools, and external devices, restraints, and mobility aids.
- g) The Contractor shall use the human engineering standards listed in section 2.8.7, Human Engineering, to design all interfaces to suits, EVA, and survival crew equipment systems.
- h) The contractor shall provide EVA handling aids mounted to the exterior of the ISS CCA to support installation, activation, and check out.
- i) RESERVED
- j) The Contractor shall develop, implement, and maintain a Suits, EVA, and Survival Crew Equipment Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of the Suits, EVA, and Survival Crew Equipment Support Systems.
- k) The Contractor shall document the design for the Suits, EVA, and Survival Crew Equipment Support Systems as specified in **DRD CEV-T-072**, Suits, EVA, and Survival Crew Equipment Support Systems Design and Data Book.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-072: Suits, EVA and Survival Crew Equipment Support Systems Design and Data Book

The following subsystem specific information is collected in the DRDs specified in Section 10.2

- DRD CEV-T-015: Suits, EVA, and Survival Crew Equipment Support Systems Volume - Master Verification Plan

2.6.12 Environmental Control and Life Support (ECLS), Crew Health and Habitation Accommodations Integration

The Contractor shall integrate the DDT&E efforts of the spacecraft subsystems for Environmental Control and Life Support (ECLS), active thermal control, medical systems interfaces, and habitation accommodations.

- a) NASA will provide food and food packaging. The Contractor shall design the interfaces for these NASA-provided items.
- b) NASA will provide portable medical kits, equipment and supplies, and portable countermeasures systems. The Contractor shall design the interfaces for these NASA-provided items.
- c) NASA will provide additional FCE such as personal hygiene kits, hygiene consumables, sleep restraints, portable supplemental lighting, portable vacuum cleaner, dust abatement system, disposable wipes, personal carry-on stowage, standard tools, crew clothing, and portable crew personal items (e.g., relaxation and entertainment systems). The Contractor shall design the interfaces for these NASA-provided items in accordance with the following document:
 - CXP-70035, Portable Equipment, Payloads, and Cargo IRD

Crew Exploration Vehicle – (CEV)

Modification 994

- d) NASA will provide active and passive radiation instrumentation. The Contractor shall design the interfaces for these NASA-provided items.
- e) The Contractor shall use the following ECLS, crew health and habitation accommodations standards and the Human Engineering Standards listed in Section 2.8.7, Human Engineering, for designing this subsystem:
 - o JSC 20584, Spacecraft Maximum Allowable Concentrations for Airborne Contaminants
- f) The Contractor shall provide definition of the process to be used for cleanliness of components for use in oxygen, fuel, and pneumatic systems. The Contractor shall provide this information in **DRD CEV-T-073, Environmental Control and Life Support Design and Data Book**. The process must meet or exceed the requirements identified in the following documents:
 - o MSFC-SPEC-164B, Specification for Cleanliness of Components for Use in Oxygen, Fuel and Pneumatic Systems (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List)
 - o MSFC-PROC-404, Gases, Drying and Preservation, Cleanliness Level and Inspection
 - o MSFC-PROC-1831, The Analysis of Nonvolatile Residue Content
 - o MSFC-PROC-1832, Sampling and Analysis of Nonvolatile Residue Content on Critical Surfaces
- g) The Contractor shall identify the standard for test methods for environmental engineering in **DRD CEV-T-073, Environmental Control and Life Support Design and Data Book**. This standard shall meet or exceed the following standard:
 - o MIL-STD-810F, DOD Test Method Standard for Environmental Engineering Considerations and Laboratory Tests, Section 5 and Part 2.
- h) The Contractor shall develop, implement, and maintain an ECLS Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of the ECLS system.
- i) The Contractor shall document the design for the Habitation Accommodations as specified in **DRD CEV-T-074, Habitation Accommodations Design and Data Book**.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-073: Environmental Control and Life Support Design and Data Book
- DRD CEV-T-074: Habitation Accommodations Design and Data Book

The following subsystem specific information is collected in the DRDs specified in Section 10.2

- DRD CEV-T-015: ECLS Volume - Master Verification Plan

2.6.13 Pyrotechnics Integration

The Contractor shall integrate all CEV mounted devices and assemblies containing or operated/actuated/severed by, propellants and/or explosives.

- a) NASA will supply the pyrotechnic initiators for all pyrotechnic events excluding mechanically initiated devices. NASA will supply interface and performance requirements for the system used to fire the initiators.
- b) If the Contractor selects existing Shuttle pyrotechnic devices for the CEV Spacecraft, then NASA will supply those pyrotechnic devices

Crew Exploration Vehicle – (CEV)

Modification 904

- c) NASA will supply pyrotechnic reefing line cutters used in the CPAS.
- d) The Contractor shall comply with all requirements in JSC 62809, Constellation Spacecraft Pyrotechnic Specification and JPR 8080.5 Standards P1-P7.
- e) The Contractor shall perform preliminary design reviews and critical design reviews for each pyrotechnic device not provided by NASA. The Contractor shall conduct development, qualification, and acceptance testing on all other pyrotechnic devices selected for the CEV Spacecraft. The Contractor shall conduct Phase I, Phase II, and Phase III technical reviews on all other pyrotechnic devices selected for the CEV Spacecraft per the requirements of JSC 62809, Constellation Spacecraft Pyrotechnic Specification.
- f) The Contractor shall perform stress analysis and deliver stress analysis reports (**DRD CEV-T-062, Stress Analysis Report**) on all pyrotechnic devices selected for the CEV Spacecraft.
- g) The Contractor shall develop, implement, and maintain an Pyrotechnics System Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of the pyrotechnics system.
- h) The Contractor shall use the following standards for designing the pyrotechnics subsystem:
 - o AFJMAN 24-204, Preparing Hazardous Materials for Military Air Shipments
 - o AFCPCMAN 91-710 Eastern and Western Range Safety User Requirements
 - o FED-STD-H28/20, Screw - Thread Standards for Federal Services Revision A or Later Inspection Section 20 Methods for Acceptability of UN, UNR, UNJ, M, and MJ Screw Threads
 - o JSC 20431, NASA JSC Neutron Radiography Specification
 - o JSC 62809, Constellation Spacecraft Pyrotechnic Specification for Production Flight tests
 - o JSC/SKD 26100132, Performance Specification for NSTS Use of Percussion Primers
 - o NASA-STD-8739.3 Soldered Electrical Connections
 - o MIL-DTL-398, RDX (Cyclotrimethylenetrinitramine)
 - o MIL-DTL-45444, HMX (Cyclotetramethylenetetranitramine)
 - o MIL-L-3055, Type I Lead Azide
 - o MIL-L-46225, Lead Azide RD-1333
 - o MIL-P-20444C, Primer, Percussion, M42 Parts for and Loading, Assembling and Packaging
 - o MIL-P-387, Pentaerythrite Tetranitrate (PETN)
 - o JPR 8080.5 Standards P1-P7
 - o MIL-STD-286, Military Standard Propellants, Solid: Sampling Examination and Testing; Method 802.1
 - o MIL-STD-810, Environmental Test Methods and Engineering Guidelines
 - o MIL-STD-2073-1, Department of Defense Standard Practice for Packaging
 - o WS 5003F, Material Specification for HNS Explosive
- i) The Contractor shall identify their standards for designing the pyrotechnics subsystem, in the following areas. This standard shall meet or exceed the following standards:
 - o AIA/NAS NASM20995, Wire, Safety or Lock
 - o ANSI/ASQC Z1.4, Sampling Procedures and Tables for Inspection by Attributes
 - o ANSI/NCSL Z450-1, Calibration Laboratories and Measuring and Test Equipment - General Requirements
 - o ASME B46.1, Surface Roughness, Waviness and Lav
 - o ASTM E1742, Standard Practice for Radiographic Examination
 - o ASTM E8, Standard Test Methods of Tension Testing of Metallic Materials
 - o DOD 4145.26-M, DOD Contractors' Safety Manual for Ammunition and Explosives
 - o MIL-P-116, Preservation, Methods of

Crew Exploration Vehicle – (CEV)

Modification 994

- MIL-STD-2073-1, Department of Defense Standard Practice for Packaging
 - MIL-S-22473, Sealing, Locking and Retaining Compounds, Single Component
 - MS20003, Indicator, Humidity, Card, Three Spot, Impregnated Areas
- j) The Contractor shall document the design for the Pyrotechnics Integration as specified in **DRD CEV-T-075**, Pyrotechnics Subsystem Design and Data Book.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-062: Stress Analysis Report
- DRD CEV-T-075: Pyrotechnics Subsystem Design and Data Book

The following subsystem specific information is collected in the DRDs specified in Section 10.2

- DRD CEV-T-015: Pyrotechnics Volume - Master Verification Plan

2.6.14 Reserved**2.6.15 Guidance, Navigation, and Control (GN&C) Integration**

The Contractor shall integrate the DDT&E efforts of the Guidance, Navigation, and Control (GN&C) subsystem including the Integrated CEV Flight Dynamics design.

- a) The CEV GN&C requirements design and functional verification effort will be performed through the use of specialized mode teams. NASA and the Contractor will co-lead the development of detailed design requirements for the CEV GN&C flight system. The Contractor shall document the GN&C requirements in **DRD CEV-T-031**, *CEV GN&C Subsystem Requirements Specification*, and **DRD CEV-T-048**, *Software Requirements Specification*. The Contractor shall provide support to the following teams:
- CEV Ascent/Abort Mode Team
 - Entry GN&C Mode Team
 - On-Orbit GN&C Mode Team
 - Flight Mechanics/Mission Design Mode Team
- b) NASA will perform independent requirements validation and design certification in key areas. In these key areas NASA will establish design requirements teams intended to integrate the activities of NASA and the Contractor. The Contractor shall participate in and support these design requirements teams for GN&C Flight Software
- c) The Contractor shall develop, implement, and maintain an GN&C System Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of the GN&C system.
- d) The Contractor shall document the design for the GN&C subsystem as specified in **DRD CEV-T-078**, GN&C Subsystem Design and Data Book.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-078: GN&C Design and Data Book

The following subsystem specific information is collected in the DRDs specified in Section 6.1.2

- DRD CEV-T-031: GN&C <Subsystem> Requirements Specification
- DRD CEV-T-031: GN&C <Components> Requirements Specification

The following subsystem specific information is collected in the DRD specified in Section 6.5.2

Crew Exploration Vehicle – (CEV)

Modification 994

- DRD CEV-T-048: Software Requirements Specification
- The following subsystem specific information is collected in the DRDs specified in Section 10.2
- DRD CEV-T-015: GN&C Volume - Master Verification Plan

2.6.16 Wiring Integration

The Contractor shall integrate the DDT&E efforts of the wiring harnesses and optical cabling for both electrical and optical signals and provides the power, data, and command paths, connections, production breaks, and access points required to develop, assemble, test, operate, verify, certify, service and safeguard the CEV Spacecraft throughout its life cycle.

- The Contractor shall develop and document the process for defining, fabricating, testing, routing, installing, verifying, and maintaining the CEV wiring subsystem throughout the life cycle, including vehicle modifications, upgrades, and discrepancy resolution. This process shall be documented in the **DRD CEV-T-079, CEV Wiring Plan**.
- The Contractor shall develop a wiring database that provides definition down to the level of pin-to-pin connectivity for all electrical harnesses and optical cables used on the CEV for ground, launch, flight, and recovery operations including testing, verification, calibration, and maintenance. The Contractor shall deliver the wiring database to NASA as **DRD CEV-T-080, CEV Wiring Database and Reports**.
- The Contractor shall develop, implement, and maintain a Wiring Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of the wiring system.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-079: CEV Wiring Plan
- DRD CEV-T-080: CEV Wiring Database and Reports

The following subsystem specific information is collected in the DRDs specified in Section 10.2

- DRD CEV-T-015: Wiring Volume - Master Verification Plan

2.7 Flight and Ground Operations Integration

CEV Operations is a NASA-led function with the Contractor providing the necessary data products, operational requirements, and support for NASA to develop the plans, processes, procedures, and tools to operate the CEV System. Operations includes the development and implementation of the processes, plans, system requirements, support and reference documents, training, procedures, and work associated with the preparation, launch and flight execution, and recovery of the CEV spacecraft. The scope of operations includes use of the CEV System hardware/software after delivery to NASA in support of the preparation and execution of the Ares-1Y, Orion-1 and Orion-2 operational flights.

The two principle areas of operations are ground operations and flight operations. Ground operations are activities associated with the processing of the flight hardware using ground systems for the launch and post-landing operations. These activities include the planning, pre-launch processing, launch, and post-landing operations. Flight operations are activities performed to support the spacecraft and crew to accomplish the mission objectives. The scope of flight operations includes the early preflight analyses and design, flight planning, flight product and procedure development, flight training, and flight execution by the crew and mission operations.

2.7.1 Operational Analysis Supporting Design

- a) The Contractor shall participate with Constellation Operations in the development of operations plans involving multiple systems across the Constellation Program.
- b) The Contractor shall provide a concept of operations for the CEV in accordance with **DRD CEV-O-001**, *Contractor's CEV Concept of Operations*, using ANSI/AIAA-G043-1992, Guidance for the Preparation of Operational Concept Documents, paragraph 4.0 and Appendix A, as guidance documents.
- c) The Contractor shall perform and update operational analyses using operations requirements analysis and operations assessment analysis processes for implementation per SOW Sections 2.4, Integrated Analysis, 2.3 (a), CEV to Constellation Program Integration, and 2.3 (b), CEV to ISS Program Integration in accordance with **DRD CEV-T-010**, *System Performance Analysis Report*, to ensure a balance of cost, schedule and risk between spacecraft design and ground and flight infrastructure needed to accomplish the operational mission. These operational analyses will produce an “operational view” that describes how the system products serve the operators (e.g. flight crew, ground operations, and flight operations). The Contractor shall provide operational analyses that establish lifecycle operation and support requirements for the system. These operational analyses shall be sufficient for use by NASA to determine how best to provide operational support, determine under what environmental conditions the system products may be used, and how well they may perform under anticipated conditions. The Contractor shall incorporate the applicable human-to-machine interface considerations for ground processing from the CXP-70024, Constellation Human System Integration Requirements (HSIR) and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List). Example subjects for operational analyses include:
 - o Reduction and consolidation of flight-to-ground interface points in addition to flight-element to flight-element interfaces;
 - o Use of common/consistent fasteners, connectors, and consumables/propellants;
 - o Use of non-toxic consumables;
 - o Design of Line Replaceable Units (LRUs) that allows for removal, replacement and retest throughout the ground processing flow;
 - o Use of design that allows for in-space maintenance;
 - o Minimize operational constraints on vehicle in-space attitudes caused by design limitations in such systems as communications, thermal, or power system; and
 - o Design of flight software architecture for less costly maintenance and certification following updates.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-O-001: Contractor's CEV Concept of Operations

The following Operational Analysis specific data is collected in the DRD specified in Section 2.4

- DRD CEV-T-010: System Performance Analysis Report

2.7.2 Ground Operations Integration

Ground Operations will be the responsibility of the NASA; however, it is essential that the Contractor participate with NASA in the overall planning and implementation of ground operations.

Ground Operations Integration includes efforts required to provide (1) plans for CEV stand-alone ground operations where the activities involve the CEV system and (2) requirements for integrated ground operations where the activities involve the spacecraft with other Constellation flight elements. It also includes tasks to develop concepts, requirements and plans for maintenance and logistics for CEV Project supportability for operations. These activities are generally performed in cooperation with the CxP Ground Operations Project.

- a) The Contractor shall develop, implement and update **DRD CEV-T-011, Integrated Logistics Support Plan**, using the CXP-70064, Constellation Program Supportability Plan as informational.
- b) The Contractor shall perform a *Logistics Support Analysis (DRD CEV-T-012)* in accordance with the **DRD CEV-T-011, Integrated Logistics Support Plan**.
- c) The Contractor shall perform iterative design evaluations utilizing the results of on-going reliability, maintainability, and supportability assessments to identify logistics impacts and apply these evaluations to the design of the system in order to minimize the identified logistics impacts.
- d) The Contractor will provide initial flight spares per Sections 2.10 CEV Assembly, Integration, and Production, 6.1.3 CM Flight Spares, 6.2.3 SM/SA Flight Spares, 6.4.3 LAS Flight Spares; initial ground support equipment spares per Section 2.7.2(e), Ground Support Equipment; and planning for storage of spares per Section 2.7.2 (b), Storage. The Contractor shall participate in the Government-sponsored Provisioning Guidance Conference and lead CEV Provisioning Conferences.
- e) The Contractor shall develop and maintain a launch site forecast of CEV propellants, fluids, and gases for the CEV Project life cycle per **DRD CEV-T-013, Launch Site CEV Propellants, Fluids, and Gases Forecast**.
- f) The Contractor shall provide and maintain data to support a Logistics Management System (LMS) for the tracking and management of equipment, spares, repair parts, supplies, material, and shipping containers, and identify excess or obsolete assets and initiate disposal. The LMS applies to both ground-based and space-stored assets.
- g) The Contractor shall develop the capability within the CEV spacecraft to interface/utilize the LMS for on-board inventory management.
- h) The Contractor shall deliver all supportability data developed and acquired for the design and manufacturing of CEV spacecraft to support flight hardware and Ground Support Equipment (GSE) procurement, remanufacturing, refurbishment, failure analysis, and repair in accordance with **DRD CEV-T-014, Supportability Data Package**.
- i) The Contractor shall name CEV spacecraft components, assemblies, data products, applications and operations consistently in accordance with CXP-02007, Constellation Nomenclature Plan.
- j) The Contractor shall test (acceptance test only) and deliver flight spares. The Contractor shall provide a spare parts list as part of the **DRD CEV-T-012, Logistics Support Analysis (Recommended Spare Parts List)**. (IDIQ)
- k) The Contractor shall deliver one ship set of flight spares (i.e., 1 copy of every line replaceable unit) (IDIQ)
- l) The Contractor shall support NASA ground operations in the development of a CEV ground operations plan addressing pre-launch processing, launch operations, and post-landing operations to ensure that ground operations activities are appropriately planned and implemented. Examples of Contractor support to NASA ground operations include: provide flight and ground design data, provide technical assistance to the system integrated testing approach, identify support requirements for vehicle processing, provide technical expertise

Crew Exploration Vehicle – (CEV)

Modification 904

during the operations reviews, and provide work force resource loading forecasts for ground operations activities involving Contractor-provided hardware and software. (IDIQ)

- m) The Contractor shall develop and update the flight hardware/software operations and maintenance plans and requirements for ground operations in accordance with **DRD CEV-O-002, Flight Hardware/Software Operations and Maintenance Requirements Development Plan and Requirements Document**. The Contractor shall coordinate flight hardware/software operations and maintenance plans and requirements development with NASA.
- n) The Contractor shall provide flight and ground hardware/software technical assistance during ground operations phases to support ground operations activities, ensure operations and maintenance requirements implementation, assist in element-to-element integrated testing, assist in flight hardware/software corrective action disposition, ensure consistent, clear communications between the Contractor and NASA ground operations, and provide an advocate between the ground operations organizations and the spacecraft designers. (IDIQ)
- o) NASA will implement the requirements as defined in the **DRD CEV-O-002, Flight Hardware/Software Operations and Maintenance Requirements Development Plan and Requirements Document**, during ground operations. The Contractor shall assess and provide recommendations regarding changes to the NASA-developed ground operations procedures to assure that the changes are consistent with the CEV Spacecraft and GSE requirements, constraints, and capabilities. (IDIQ)
- p) For work that is to be accomplished by the Contractor at either KSC or CCAFS, the Contractor shall develop and update the support requirements in compliance with KSC-HB-GP60-3 ASRS Handbook and in accordance with **DRD CEV-O-003, Launch Site Support Requirements Documentation**.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-O-002: Flight Hardware/Software Operations and Maintenance Requirements Development Plan and Requirements Document
- DRD CEV-O-003: Launch Site Support Requirements Documentation
- DRD CEV-T-011: Integrated Logistics Support Plan
- DRD CEV-T-012: Logistics Support Analysis
- DRD CEV-T-012: Logistics Support Analysis (Recommended Spare Parts List). (IDIQ)
- DRD CEV-T-013: Launch Site CEV Propellants, Fluids, and Gases Forecast
- DRD CEV-T-014: Supportability Data Package

2.7.2.(a) Facilities and Facility Systems

The ground facilities and facility systems encompass processing facilities, control rooms, landing and recovery facility systems and other monitoring systems.

- a) The Contractor shall develop and update end item-level requirements in accordance with **DRD CEV-O-008, Ground Systems Requirements, Plans, Reports, and Design Data, Volume I, Ground Systems End Item Requirements Document and Report**.
- b) The Contractor shall support NASA in the requirements development; and in the design, development, modification, and implementation activities for the facilities and facility systems that will be provided by NASA. Examples of Contractor support include: provide flight hardware/software interface design and data; participate in the design reviews, working groups, and technical interchange meetings; ensure Contractor requirements are implemented appropriately; and participate in the activation and verification of NASA provided facilities and facility systems. (IDIQ)

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-O-008: Ground Systems Requirements, Plans, Reports and Design Data
- DRD CEV-O-007: Range Safety Requirements Documents

2.7.2.(b) Storage

Ground Systems Storage includes the development of requirements for storage facilities for flight and ground systems and logistical spares provided by the CEV Contractor.

- a) The Contractor shall develop the requirements for the storage of Contractor-provided flight hardware and logistical spares in accordance with **DRD CEV-O-002**, *Flight Hardware/Software Operations and Maintenance Requirements Development Plan and Requirements Document*.
- b) The Contractor shall develop the requirements for the storage of Contractor-provided ground systems and logistical spares in accordance with **DRD CEV-O-008**, *Ground Systems Requirements, Plans, Reports, and Design Data, Volume I, Ground Systems End Item Requirements Document and Report*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-O-002: Flight Hardware/Software Operations and Maintenance Requirements Development Plan and Requirements Document
- DRD CEV-O-008: Ground Systems Requirements, Plans, Reports and Design Data Volume I, Ground Systems End Item Requirements Document and Report

2.7.2.(c) Transportation

- a) The Contractor shall perform the planning and implementation for government furnished transportation support of CEV spacecraft element or equipment other than that provided in Section 2.10. The Contractor shall work with the appropriate NASA Ground Operations organizations to coordinate the implementation of government furnished transportation of CEV elements and equipment. These plans shall be included in **DRD CEV-T-087** CEV Spacecraft Handling and Transportation Plan.
- b) The Contractor shall develop and implement plans detailing the design and construction of all CEV transportation support equipment, and the plans for transportation of the CEV Spacecraft elements to and from Government Furnished transportation locations, test facility locations, processing sites, and/or launch/landing sites. These plans shall be included in **DRD CEV-T-087**, *CEV Spacecraft Handling and Transportation Plan*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-087: CEV Spacecraft Handling and Transportation Plan

2.7.2.(d) *CEV Ground and Training Systems*

Ground Systems include facilities, facility systems, and support equipment hardware and software required for ground and flight operations. NASA will provide all ground systems facilities, facility systems, and a portion of the support equipment.

Training Systems include facilities, hardware and software to support ground and flight operations training.

NASA operations will develop the training products and conduct the operations training and certification for ground and flight operations.

- a) For ground operations, the Contractor shall provide support for NASA development of training materials. Examples of Contractor support include: provide technical assistance in flight hardware processing, handling, and safety considerations; and provide an advocate between the ground operations' training organization and the spacecraft designers. (IDIQ)

2.7.2.(e) *Integrated Ground Support Equipment*

Ground Support Equipment (GSE) includes hardware and software needed for ground operations.

- a) The Contractor shall support NASA in developing the allocation list of GSE to be provided by the Contractor. The allocation list will include GSE end items required to support SOW Sections 6.5, CEV Software, 10.3 Integrated Test and Verification, 2.7.2, Ground Operations Integration, and 10.6, Flight Test. The Contractor shall identify all Contractor-provided GSE in Attachment J-9, Deliverable Items List. The NASA-provided GSE described in Attachment J-11, Government Furnished Property List, will be delivered to NASA ground operations for the RRF and operational flights. Contractor use of the NASA-provided equipment will be determined during the allocation list development. Examples of the types of GSE to be provided by the Contractor include:
 - o Lifting Devices – Contractor to provide lifting slings and adapters from Hydraset down to spacecraft elements/components
 - o Fluid and Gases Servicing Systems – Contractor to provide spacecraft interfacing connections
 - o Command, Control and Monitoring System – Contractor to provide CEV standalone Command, Control and Monitoring System
 - o Facility Infrastructure Systems – Contractor to provide spacecraft specialty systems (Spacecraft specific special electrical power supplies, data handling, etc.)
 - o Access stands – Contractor to provide internal access equipment
 - o Special tools – Contractor to provide spacecraft specific special tools and ancillary equipment (LRU installation and removal devices and tools, inspection tools,)
 - o Special Test equipment – Contractor to provide special test equipment (Cabin Leak test equipment, Data bus test equipment, etc.)
- b) The Contractor shall develop and update the GSE Specification in accordance with **DRD CEV-T-031**, *CEV <System> Requirements Specification*, for Contractor-provided GSE. The Contractor shall ensure that the GSE Specification is consistent with **DRD CEV-O-001**, *Contractor's CEV Concept of Operations* and balances performance, life-cycle cost,

Crew Exploration Vehicle – (CEV)

Modification 904

schedule, and risk. The Contractor shall develop and update the **DRD CEV-T-035, Internal Interface Requirements Document**, for all interfaces with flight hardware, NASA and Contractor-provided GSE, facility systems, and facilities. The Contractor shall develop and update the **DRD CEV-T-029, Interface Control Document**, for all interfaces with flight hardware, NASA and Contractor-provided GSE, facility systems, and facilities.

- c) The Contractor shall develop and update the contractor provided GSE end item-level requirements in accordance with **DRD CEV-T-031**, CEV <GSE Subsystem> Requirements Specifications and CEV <GSE Component> Requirements Specifications. The Contractor shall use the following applicable documents:
 - o NASA-STD-5005B: NASA Standard for Ground Support Equipment (and associated Applicable Document Children as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List).
- d) The Contractor shall develop and update the NASA provided GSE end item-level requirements in accordance with **DRD CEV-O-008**, Ground Systems Requirements, Plans, Reports, and Design Data, Volume I, Ground Systems End Item Requirements Document and Report. The Contractor shall use the following applicable documents:
 - o NASA-STD-5005B: NASA Standard for Ground Support Equipment (and associated Applicable Document Children as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List).
- e) The Contractor shall design, develop, produce, integrate, verify, validate, certify, document, and deliver integrated CEV GSE in accordance with all requirements in CXP-72000, Systems Requirements for the Crew Exploration Vehicle Element (CEV SRD), and in this SOW, and in accordance with **DRD CEV-O-008, Ground Systems Requirements, Plans, Reports, and Design Data, Volume II, Ground Systems End Item Implementation Plan and Report**. The Contractor shall provide common GSE for use during multiple phases including manufacturing, transport, processing, operations, and integration. The Contractor shall provide a common CM handling and transportation fixture. The Contractor shall assess existing material equipment lists for existing programs for any GSE hardware items that can be used for CEV. The Contractor shall plan for and deliver the GSE end items 90 days prior to first need date. The Contractor shall use the following applicable documents for design and development of Contractor-provided GSE:
 - o NASA-STD-5005B: NASA Standard for Ground Support Equipment (and associated Applicable Document Children as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List).
- f) The Contractor shall support NASA in the requirements development, design, modification, and implementation activities for the GSE that will be provided by NASA. Examples of Contractor support include: provide flight hardware/software interface design and data; participate in design reviews, working groups, and technical interchange meetings; ensure Contractor requirements are implemented appropriately; and participate in the test and verification of the NASA-provided GSE. (IDIQ)
- g) The Contractor shall develop and update **DRD CEV-O-008**, Ground Systems Requirements, Plans, Reports, and Design Data, Volume IV, Ground Systems Sustaining Engineering Plan, for the Contractor-provided GSE.
- h) NASA will perform the GSE sustaining engineering activities. The Contractor shall support NASA sustaining engineering activities. Examples of Contractor support include: provide engineering support for problem resolution including Material Review Board (MRB) items; provide engineering review and analysis of proposed upgrades and modifications; review FMEA-CIL and hazard analysis identified critical items for mitigation or elimination; and provide an advocate between the ground operations organizations and the GSE designers. (IDIQ)
- i) The Contractor shall develop and deliver **DRD CEV-T-040, Acceptance Data Package**, for each Contractor-provided GSE end item.

Crew Exploration Vehicle – (CEV)

Modification 904

- j) The Contractor shall provide initial spares, concurrent with the delivery of the GSE end items and in accordance with the provisioning procedures in **DRD CEV-T-011**, *Integrated Logistics Support Plan*, and **DRD CEV-T-012**, *Logistics Support Analysis*, for all Contractor-provided GSE. (IDIQ)
- k) The Contractor shall complete the DD-250 for the Contractor-provided GSE and deliver the Contractor-provided GSE to the NASA-designated facilities.
- l) The Contractor shall develop and update 2-D and 3-D simulation models of the Contractor-provided spacecraft and Contractor-provided GSE to assess clearances, placement, conflicts and the moving of hardware in accordance with **DRD CEV-T-003**, *CEV CAD Models*. The Contractor shall develop and deliver these models in accordance with SOW Section 2.4.
- m) The Contractor shall develop, implement, and maintain an GSE Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of GSE system.
- n) The Contractor shall develop and maintain **DRD CEV-T-032**, CEV Specification and Drawing Trees for GSE.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-O-008: Ground Systems Requirements, Plans, Reports, and Design Data
- DRD-CEV-T-029: GSE Interface Control Documents
- DRD-CEV-T-031: GSE <System> Requirements Specification
- DRD-CEV-T-031: GSE <Subsystem> Requirements Specification
- DRD-CEV-T-031: GSE <Component> Requirements Specification
- DRD CEV-T-032 GSE Specification and Drawing Tree
- DRD-CEV-T-035: GSE Intererface requiremetns Document
- DRD-CEV-T-040: Acceptanc Data Package

The following GSE data is incorporated in the DRD specified in Section 2.4:

- DRD CEV-T-003: CEV CAD Models

The following GSE specific information is collected in the DRDs specified in Section 10.2:

- DRD CEV-T-015: GSE Volume Master Verification Plan

2.7.3 Flight Operations Integration

Flight Operations include the plans, processes, schedules, and products required to perform the flight design, analyses, and flight planning activities; flight products and procedure development; and execution of Ares 1-Y, Orion 1, and Orion 2 operational flights. Flight operations will be the responsibility of NASA; however, it is essential that the Contractor provide the data and support to NASA for the development of the flight operations products to prepare for and execute the CEV missions.

2.7.3.(a) Flight Operations Preparation

Flight Operations Preparation is the development of the pre-flight plans, processes, schedules, flight design and analyses, flight plans, procedures, and support products necessary to prepare for the CEV mission execution. The culmination of these activities will produce a complete, integrated set of operations products and procedures necessary to execute a CEV mission.

Crew Exploration Vehicle – (CEV)

Modification 994

A single authoritative source of vehicle design and performance data is required to develop, produce, and implement the flight design process, trade studies, analyses, simulations, and flight products and procedures.

- a) The Contractor shall develop and update vehicle systems, flight design, and analysis data for the CEV spacecraft in accordance with **DRD CEV-O-004**, *CEV Operations Data Book*,
 - o Volume I: CEV Spacecraft Systems Performance and Constraints Data
 - o Volume II: CEV Spacecraft Systems Electrical Equipment List
 - o Volume III: CEV Mission Mass Properties Data
 - o Volume IV: CEV Spacecraft Systems Contingency Analysis Data
 - o Volume V: CEV Aerodynamic and Astrodynamic Performance and Constraints Data
 - o Volume VI: CEV Crew Module Landing and Emergency Rescue Data
 - o Volume VII: CEV Flight Capability Envelopes
 - o Volume VIII: CEV Ascent, Entry, and On-orbit Structural Envelopes
- b) The Contractor shall develop the initial procedures inputs in accordance with **DRD CEV-O-005**, *Flight Operations Procedures Data*. These provide nominal operations, maintenance, and nominal/off-nominal time critical response CEV spacecraft procedure inputs.
- c) The Contractor shall develop the CEV stowage procedures, and supporting documentation in accordance with **DRD CEV-O-006**, *CEV Stowage Capabilities and Services Handbook*.
- d) The Contractor shall provide support to the NASA flight operation's systems, flight planning and cargo integration, and flight design and analysis disciplines. The Contractor shall ensure consistent, clear communications between the Contractor and NASA flight operations, and shall research and disseminate the necessary data and technical information from the spacecraft designers for NASA to develop its flight products. Examples of Contractor support to NASA flight operations include: provide technical assistance during NASA's development of the flight crew and flight controller procedures, flight rules, flight plans, system briefs, reference products, flight design and analysis tools, system analysis tools, telemetry parameter selection, displays necessary to prepare for and execute CEV flight operations, and provide an advocate between the flight operations organizations and the spacecraft designers. (IDIQ)
- e) The Contractor shall assess and provide recommendations regarding flight rule change requests and procedures change requests to assure that changes are consistent with CEV spacecraft requirements, constraints, and capabilities. (IDIQ)

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-O-004: CEV Operations Data Book
- DRD CEV-O-005: Flight Operations Procedures Data
- DRD CEV-O-006: CEV Stowage Capabilities and Services Handbook

2.7.3.(b) Flight Operations Execution (IDIQ)

Flight Operations Execution encompasses real-time support for all phases of mission operations beginning with pre-launch activities through post-landing egress of the flight crew. It is the culmination of all of the earlier pre-flight flight design, mission planning, training, and ground operations activities.

- a) The Contractor shall provide support during the execution of the CEV missions using the Contractor personnel supporting the NASA flight operation's systems, flight planning and cargo integration, flight design and analysis, and training disciplines.

Crew Exploration Vehicle – (CEV)

Modification 904

- b) The Contractor shall provide engineering support during flight execution to provide technical information, interpret systems health data, and perform in-depth analysis in response to anomalous spacecraft conditions. The Contractor shall support the NASA CEV sub-system managers.

2.7.4 Range Safety Integration

Test and operational flights of the CEV from U.S. airspace and ranges will require interaction with the agency responsible for the range. Support to Range Safety includes the technical and management efforts to assemble the appropriate team; develop and prepare plans for compliance with range safety requirements during design, development, preparation and execution of CEV test and operational flights; establish meetings and reviews with range safety personnel and the CEV subsystems personnel; coordinate with NASA operations personnel; and obtain range safety support to hazardous activities at the launch and test flight sites, launch operations, and hazards analysis for the launch/ascent and the descent/landing phases.

- a) In association with the CLV Project and the launch vehicle contractors, the Contractor shall define and resolve range safety issues in support of CEV system development, and provide data necessary to gain approval of the range safety requirements in accordance with **DRD CEV-O-007, Range Safety Requirements Documents**. The Contractor shall incorporate the requirements set developed in accordance with **DRD CEV-O-007** into the appropriate CEV Spacecraft and GSE specifications delivered in **DRD CEV-T-031, CEV <System> System Requirements Specification** and **DRD CEV-T-031, CEV <GSE> System Requirements Specification**.
- b) The Contractor shall use the following applicable standards for **DRD CEV-O-007, Range Safety Requirements Documents**:
- AFSPCMAN 91-710: Range Safety User Requirements Manual
 - NPR 8715.5, Range Safety Program
 - Range Commanders Council - Range Safety Group - Standard 321-02: Common Risk Criteria for National Test Ranges

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-O-007: Range Safety Requirements Documents

The following GSE related Range Safety data is collected in the DRD specified in Section 2.7.2

- DRD CEV-T-031: CEV <System> System Specification
- DRD CEV-T-031: CEV <GSE> System Specification

2.7.5 Training Systems (IDIQ)

NASA will provide the Training Systems necessary to prepare the crew, ground, and flight operations personnel for successful execution of CEV missions.

- a) For ground operations training systems, the Contractor shall support NASA in the implementation of the training systems requirements. Examples of the support include: provide flight hardware interface design and data; participate in the design reviews, working groups, and technical interchange meetings; and participate in the test and verification of the NASA-provided training systems.
- b) The Contractor shall provide support to assist NASA's development of the CEV simulators and mockups used for crew and flight controller training, procedure verification, real-time support, and control center testing. Examples of Contractor support include: provide flight

Crew Exploration Vehicle – (CEV)

Modification 994

hardware interface design and data; participate in the design reviews, working groups, and technical interchange meetings; and participation in the test and verification of the NASA-provided training systems.

2.7.6 Training

NASA operations will develop the training products and conduct the operations training and certification for ground and flight operations.

- a) The Contractor shall provide NASA operations access to all data products produced by the Contractor, its subcontractors, and its vendors for the purpose of their in-house training and familiarization of the CEV System and its subsystems. The Contractor shall provide the data products in accordance with SOW Section 1.5 (a), NASA ICE.
- b) For flight operations, the CEV Contractor shall provide support to the NASA training organization. The Contractor shall ensure consistent, clear communications between the Contractor and the NASA training organization, and shall provide technical assistance during NASA's development of the training materials necessary to prepare the flight crew, flight controllers, and other flight operations personnel for CEV missions. Examples of Contractor support include: research and dissemination of the necessary vehicle systems data and technical information from the spacecraft designers for NASA to develop its training products; provide preliminary vehicle design and test data, vehicle design rationale and drivers, and clarify vehicle requirements, design, and interfaces; and provide an advocate between the flight operations' training organization and the spacecraft designers. (IDIQ)
- c) The Contractor shall be responsible for maintaining all trainer-delivered hardware for assurance that the hardware receives all upgrades and all fixes.
- D) NASA shall support the Contractor in "Test Participation " training and CAIL familiarization of Crew members for Contractor led Verifications taking place in the CAIL. NASA shall provide to the Contractor data products and Crew Operational Procedures.

2.8 Specialty Engineering

Specialty Engineering applies the crosscutting specialty engineering disciplines of materials and processes, electromagnetic compatibility, Electrical, Electronic, and Electromechanical (EEE) parts, and environments to the CEV System.

- a) The Contractor shall apply specialty engineering throughout the life cycle of the CEV System.
- b) The Contractor's approach to incorporating the engineering specialties into the systems engineering process and the technical effort required shall be documented in **DRD CEV-M-001, CEV Prime Project Management Plan**.

Deliverables

The following Specialty Engineering data is collected in the DRD specified in Section 1.1

- DRD CEV-M-001: CEV Prime Program Management Plan

2.8.1 Natural and Induced Environments

- a) The Contractor shall design the CEV System for the specific natural environments and induced environments that the CEV System must operate within and for which the CEV

Crew Exploration Vehicle – (CEV)

Modification 904

System must be qualified, encompassing all phases of CEV System production, testing and operation in all modes through disposal in accordance with CXP-70023, Constellation Program Design Specification for Natural Environments (DSNE) (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List) utilizing the CxP-70044, Constellation Program Natural Environment Definition for Design (NEDD). The Contractor shall use the applicable requirements in Contract Attachment J-3, Table 1.2, Applicable Environmental Data Documents.

- b) The Contractor shall derive, control and validate environment data and analysis models for the design, certification, and operation of the CEV System, subsystems, and components.

2.8.2 Micrometeoroid and Orbital Debris (MM/OD) Environments

- a) The Contractor shall assess MMOD risk for loss of vehicle/crew and loss of mission based on the design MMOD environments derived from CXP-70023, Constellation Program Design Specification for Natural Environments (DSNE) (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List), utilizing CxP-70044, Constellation Program Natural Environment Definition for Design (NEDD).
- b) In performing the analysis and providing the protection hardware, the Contractor shall comply with the following standards:
 - o NASA TP-2003-210788, Meteoroid/Debris Shielding, 2003, Section 2 for describing the MMOD risk assessment process using Bumper code
 - o JPR 8080.5 M/S-11, JSC Design and Procedural Standards, Section M/S-11, Meteoroid and Orbital Debris Protection Levels for Structures

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-044: CEV MMOD Analysis Report

2.8.3 Radiation Environments for Crew Exposure

- a) The Contractor shall use radiation analyses, including crew radiation exposure analysis (using analytical tools integrated to structural models), to certify that the spacecraft meets the CEV radiation requirements for the space radiation environments described CXP-70023, Constellation Program Design Specification for Natural Environments (DSNE) (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List), utilizing the CxP-70044, Constellation Program Natural Environment Definition for Design (NEDD). The Contractor shall document the certification results in **DRD CEV-T-045, CEV Space Radiation Analysis and Certification Report**.
- b) The Contractor shall use the following radiation protection requirements and applicable document(s) in the design of the CEV Spacecraft:
 - o CXP-70024, Constellation Human Systems Integration Requirements (HSIR), Section 3.2.7 per the HSIR allocation matrix in Appendix J.
 - o OSHA Standards 29 CFR, Supplementary Standards 1960.18
 - o National Council on Radiation Protection and Measurements Report No. 132: Radiation Protection Guidance for Activities in Low-Earth Orbit
 - o National Council on Radiation Protection and Measurements Report No TBD: "Radiation Protection and Science Goals for Lunar Missions"; to be published

in 2006 (Note: Upon completion, this document will replace National Council on Radiation Protection and Measurements Report No. 132: Radiation Protection Guidance for Activities in Low-Earth Orbit.)

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-045: CEV Space Radiation Analysis and Certification Report

2.8.4 Materials and Processes

- a) The Contractor shall ensure materials are selected, controlled, implemented and verified to be consistent with their intended usage environments.
- b) The Contractor shall select, treat, fabricate, inspect, test, and analyze materials of construction to ensure the safety and success of the CEV System.
- c) The Contractor shall develop and implement **DRD CEV-T-019, Materials and Processes Selection, Implementation, and Control Plan** that tailors the requirements and applicable documents of NASA-STD-(I)-6016, Standard Materials and Processes for Requirements for Spacecraft indicating the degree of conformance and method of implementation for each requirement as well as providing rationale for any requirements altered or not implemented.
- d) The Contractor shall develop and implement corona design criteria as guided by MSFC-STD-531, High Voltage Design Criteria and JPR 8080.5, E-6, JSC Design and Procedural Standard E-6, Corona Suppression. The contractor shall document and implement DRD CEV-T-024, *Corona Design Criteria*.
- e) The Contractor shall use the following applicable standards for Materials and Processes or demonstrate use of an equivalent standard:
 - IPC/EIA J-STD-001, Performance Class 3 with Space Addendum (Requirements for Soldered Electrical and Electronic Assemblies)
 - IPC-A-610, Acceptability of Electronic Assemblies - Performance Class 3
 - JPR 8080.5, E-6, JSC Design and Procedural Standard E-6, Corona Suppression
 - JPR 8080.5, E-14, JSC Design and Procedural Standard, E-14, Electrical Wire Harness Acceptance Testing
 - JPR 8080.5, E-24, JSC Design and Procedural Standard, E-24, Electrical Wire and Cable Acceptance Test
 - NASA-STD-(I)-6016, Standard Requirements for Materials and Processes for Spacecraft.
- f) The Contractor shall develop and implement DRD CEV-T-020, Materials Usage Agreements (MUA); DRD CEV-T-021, Contamination Control Plan (CCP); DRD CEV-T-022, Materials Identification and Usage List (MIUL); DRD CEV-T-023, Nondestructive Evaluation Plan.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-019: Materials and Processes Selection, Implementation, and Control Plan
- DRD CEV-T-020: Materials Usage Agreements (MUA)
- DRD CEV-T-021: Contamination Control Plan (CCP)
- DRD CEV-T-022: Materials Identification and Usage List (MIUL)
- DRD CEV-T-023: Nondestructive Evaluation Plan
- DRD CEV-T-024: Corona Design Criteria

2.8.5 EMI/EMC

- a) The Contractor shall design, develop, verify and deliver a CEV System that is electromagnetically compatible with internally generated electromagnetic energy, external electromagnetic energy environments, and the other elements of the Constellation System throughout its life cycle.
- b) The Contractor shall develop and implement **DRD CEV-T-025, CEV Electromagnetic Compatibility (EMC) Control and Verification Document** to define the plans, processes, procedures, and test data that the Contractor will use to design, construct, and verify the CEV System electromagnetic compatibility requirements.
- c) The Contractor shall tailor MIL-STD-461E, Requirements for the Control of Electromagnetic Interference (EMI) Characteristics of Subsystems and Equipment and MIL-STD-464A, Electromagnetic Environmental Effects Requirements for Systems, to assist in establishing the Contractor's documented requirements to meet the overall EMC requirements for CEV. This tailoring shall be documented in **DRD CEV-T-025, CEV Electromagnetic Compatibility Control and Verification Document**.
- d) The Contractor shall develop and design the CEV System to control and mitigate hardware malfunction and damage throughout its life cycle that can be caused by lightning. The Contractor's CEV lightning protection effort shall include the Lightning Protection Plan, the Lightning Verification Plan, and the Lightning Protection Verification Report information requested in **DRD CEV-T-025, CEV Electromagnetic Compatibility Control and Verification Document**.
- e) The Contractor shall develop and implement an Electrostatic Discharge (ESD) control program. The Contractor's electrostatic discharge control program and processes shall be documented in **DRD CEV-T-025, CEV Electromagnetic Compatibility (EMC) Control and Verification Document**. The CEV System shall be constructed and delivered in accordance with these ESD processes.
- f) The Contractor shall design and deliver a CEV System which complies with the requirements of NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment. The Contractor's processes for implementing electrical bonding requirements shall be documented in **DRD CEV-T-025, CEV Electromagnetic Compatibility (EMC) Control and Verification Document**.
- g) The Contractor shall tailor ML0303-0014, Electrical Wire Harnesses and Coaxial Cables, Installation Requirements for Electromagnetic Compatibility; SSP 30240, Space Station Grounding Requirements; and SSP 30242, Space Station Cable/Wire Design and Control Requirements for Electromagnetic Compatibility to establish the Contractor's documented requirements to meet the overall EMC requirements for the CEV System. This tailoring shall be documented in **DRD CEV-T-025, CEV Electromagnetic Compatibility Control and Verification Document**. The CEV System shall be designed, constructed, and delivered in accordance with the Contractor's wire/harness/cable installation processes.
- h) The Contractor shall participate with NASA and the Constellation Program through the Constellation E3 Control Working Group. CxP 70141, Appendix A is provided for information to coordinate and ensure CEV meets overall Constellation Program Electromagnetic Compatibility. The Contractor support to this working group will be tailored to support the functions defined in sections 4.2 and 4.3 of CxP 70141 and documented in **DRD-T-025, CEV Electromagnetic Compatibility (EMC) Control and Verification Document**.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-025: CEV Electromagnetic Compatibility Control and Verification Document

2.8.6 Electrical, Electronic, and Electromechanical (EEE) Parts

- a) The Contractor shall develop, update, and implement **DRD CEV-T-027, Electrical, Electronic, and Electromechanical Parts Management and Implementation Plan** for the CEV System.
- b) The contractor shall incorporate a control plan for ionizing radiation effects for all CEV electronics hardware as part of **DRD CEV-T-027, Electrical, Electronics, and Electromechanical Parts Management and Implementation Plan**, using informational document CxP 70144, *Constellation Ionizing Radiation Control Plan*.
- c) The Contractor shall use the following applicable standards for EEE Parts:
 - o JPR 8080.5, E-7, JSC Design and Procedural Standards, Section E-7, Electrical Components – Restrictions on Use
 - o JPR 8080.5, E-22, JSC Design and Procedural Standards, Section E-22, Ionizing Radiation Effects
- d) The Contractor shall develop and maintain DRD CEV-T-028, *As-built EEE Parts List*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-027: Electrical, Electronic, and Electromechanical Parts Management and Implementation Plan
- DRD CEV-T-028: As-Built EEE Parts List

2.8.7 Human Engineering

- a) The Contractor shall participate with NASA in the human engineering of the CEV System as specified in Section 2 Vehicle Integration, Section 6, CEV Spacecraft Development and Section 2.7.2, Ground and Training Systems. Human engineering processes will be used to ensure crew and ground personnel safety, and enhance performance, efficiency, productivity, and cost effectiveness throughout the system's expected life cycle for onboard crew, ground operators, and maintainers.
- b) The Contractor shall perform all human engineering in accordance with CXP-70024, Constellation Human Systems Integration Requirements (HSIR) (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List). The Contractor shall convert analysis data, information on human capabilities and limitations, and system requirements into (a) detail design, and (b) development plans to create human system integration concepts that operate within human capabilities, and accomplish mission objectives.
- c) The Contractor shall ensure Human Engineering personnel are integrated into the CEV development process, verify requirements for all human system interfaces, participate in each Integrated Product Team, signoff all drawings and specifications involving human system interfaces, support risk and engineering review boards, and participate in the NASA-led Cockpit Working Group.
- d) The Contractor shall use the following applicable standards for DRD CEV-T-089, Orion Crew Interface Label Map:
 - o CxP 70024, Constellation Human Systems Integration Requirements (HSIR)
 - o CxP 70152, Constellation Program Crew Interface Labeling Standard

Deliverables

The Contractor shall deliver and maintain the following document(s):

DRD CEV-T-089, Orion Crew Interface Label Map

2.9 Aerosciences

- a) NASA will develop, update, and implement aerothermal and aerodynamic databases as part of the design and development of the CEV Spacecraft. NASA will maintain the CEV aerothermal and aerodynamic databases for the duration of contract performance.
- b) NASA will define the initial Crew Module OML shape, including any flight control surfaces that might be required.
- c) NASA will control all changes to the configuration of the Crew Module OML shape through a NASA-led Crew Module OML Panel.
- d) NASA will document the development of the CEV databases with an explanation of the methodologies used to develop, populate, validate, and utilize the databases, including the following:
 - o Documentation of experimental testing, including descriptions of the model, instrumentation, facilities, test conditions, and results.
 - o Computational tool documentation describing the application of Computational Fluid Dynamics (CFD) codes and engineering tools used to populate the databases including code descriptions, gas dynamic modeling assumptions, best practices followed in grid refinement and result validation.
 - o Electronic files detailing solid model geometries, computational grids, and flowfield solutions used in creating the databases with complete descriptions of file formats and content.
 - o Assumptions and extrapolations used to incorporate experimental and computational data into the database.
 - o Specification of aerodynamic and heating uncertainties and corresponding justification.
 - o Definition of constants, variables, functions, and engineering units.
 - o Documentation of aerodynamic and aerothermodynamic verification analysis.
- e) The Contractor shall be responsible for using the aerothermal and aerodynamic databases for implementing the spacecraft design.
- f) The Contractor shall participate in an aerodynamic technical panel, which will coordinate the development, implementation, maintenance, and delivery of the aerodynamic database.
- g) The Contractor shall participate in an aerothermodynamic technical panel, which will coordinate the development, implementation, maintenance, and delivery of the aerothermodynamic database.
- h) The Contractor shall participate in the Crew Module OML Panel.
- i) The Contractor shall be responsible for developing all CAD models of the OML, subsequent to delivery of the initial NASA-defined OML.

2.10 CEV Assembly, Integration, and Production

CEV Assembly, Integration, and Production consists of all activities needed to plan for the production of an integrated, verified, and validated vehicle and for the coordination of the

Crew Exploration Vehicle – (CEV)

Modification 904

accepted vehicle and all deliverable hardware, software, and documentation products. CEV AI&P includes integrated CEV-level imagery and imagery archiving for the CEV Project.

- a) The Contractor shall integrate, assemble, certify, acceptance test, and deliver flight spacecraft meeting the requirements for the configurations identified in Sections 2.3, 6.1.6, 6.2.6, and 6.4.6 for Spacecraft, CM, SM/SA, and LAS, respectively.
- b) Reserved
- c) The Contractor shall provide to NASA test equipment, facilities, tooling or fixtures required for producing and testing mission-cycle flight articles.
- d) The Contractor shall develop and implement an imagery plan to provide imagery (e. g., still photo, motion picture, digital imagery, or video) of the CEV Spacecraft system, modules, subsystems, and components during manufacturing, assembly, test, integration, and close-out to document the hardware configuration. The Contractor shall include the plan and imagery in **DRD CEV-T-088**, *CEV Imagery Plan/Imagery Deliverables*.
- e) The Contractor's delivery plans shall include the planned method of manufacturing (including the Contractor's plans for design for manufacturability) and assembly of the flight articles(s) and associated unique tooling, fixtures and support and test equipment in accordance with **DRD CEV-T-086**, *Manufacturing and Assembly Plan*.
- f) The Contractor shall deliver 1 CEV for the Ares-1Y with the requirements specified in Section 10.6, Flight Test for the Ares 1Y (minimum functionality to support LAS abort capability; sub-orbital test).
- g) The Contractor shall deliver 2 additional production CEVs for Orion-1 (orbital test) and Orion 2 (Crewed Mission).
- h) The Contractor shall provide and maintain the non-standard ODIN hardware and software required for production activities.
- i) The Contractor shall perform facility modifications and/or upgrades as required for facility production operations. (IDIQ)

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-086: Manufacturing and Assembly Plan
- DRD CEV-T-088: CEV Imagery Plan/Imagery Deliverables

3 SAFETY, RELIABILITY, AND QUALITY ASSURANCE

Safety, Reliability and Quality Assurance includes integration of Safety and Mission Assurance into the CEV System design, development, risk identification and mitigation, test, ground and flight operations, and ground processing activities.

3.1 SR&QA Management and Administration

- a) The Contractor shall demonstrate and document compliance with requirements stated in the CXP-70059, Constellation Program Integrated Safety, Reliability and Quality Assurance Requirements for safety, reliability, maintainability, supportability, manufacturability, hardware and software quality assurance, industrial safety, and environmental safety for all aspects of the CEV System.
- b) The Contractor shall develop, implement and maintain an *Safety and Mission Assurance (S&MA) Plan* in accordance with (DRD CEV-S-001). The S&MA Plan encompasses the System Safety Plan, Industrial, Environmental and Range Safety Plan, Reliability, Maintainability and Supportability Plan, Quality Assurance Plan and the Software Assurance Plan. Each of these plans shall define the key processes and describe the methodology for accomplishment of and adherence to these processes.
- c) The Contractor shall incorporate and maintain in the Integrated Master Schedule all Constellation Safety Engineering Review Panel (CSERP) meetings and Technical Interchange Meetings (TIMs) where Orion production and Flight Test Article hazards are addressed. The Contractor shall also incorporate the S&MA DRD deliveries, including the interim deliveries of Probabilistic Risk Assessment models, hazard reports and FMEA/CILs.
- d) The Contractor shall support concurrent engineering by providing S&MA representation at program technical and management meetings, milestones and reviews (e.g., technical interchange meetings, integration meetings, review boards, safety review panels, and change control boards) and provide positions, analysis results and decision support.
- e) The Contractor shall provide S&MA representation for Constellation Safety Engineering Review Panel (CSERP) meetings and TIMs where Orion flight, ground, Flight Test Article, or integrated hazards are addressed.
- f) The Contractor shall provide an S&MA evaluation of flight rules, change requests, procedures, and contingency operations for both ground and flight operations.
- g) The Contractor shall provide S&MA support for the CEV System integrated project risk assessment for the Constellation Program.
- h) The Contractor shall generate, document, analyze and incorporate lessons learned for incorporation into NASA's Lessons Learned database.
- i) The Contractor shall provide an S&MA evaluation of all waivers, deviations, and changes with an emphasis on impacts to safety and mission success.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-S-001: Safety and Mission Assurance (S&MA) Plan

3.2 System Safety

- a) The Contractor shall develop and maintain the hazard reports in accordance with CXP-70038, Methodology for Conduct of Project Constellation Hazard Analysis (Section 6, Hazard Reports). The Contractor shall deliver all CEV System hazard reports to the Constellation Hazards Database
- b) The Contractor shall deliver flight safety data packages per **DRD CEV-S-003, Flight System Safety Hazard Analyses**, (which include the flight operations Hazard Analysis, mitigations and controls, design drawings, schematics, systems descriptions and system analysis) at all flight phased safety reviews in accordance with the project schedule and CXP-70038, Methodology For Conduct of Project Constellation Hazard Analyses.
- c) The Contractor shall deliver ground safety packages per **DRD CEV-S-005, Ground System Safety Hazard Analysis**, (which include the ground operations Hazard Analysis, mitigations and controls, design drawings, schematics, systems descriptions, hazardous operations descriptions, and launch site processing plans and procedures) at all ground phased safety reviews in accordance with the project schedule, and CXP-70038, Methodology for Conduct of Project Constellation Hazard Analysis.
- d) The Contractor shall develop and maintain fault trees analyses to identify, mitigate and control the hazards of the CEV System throughout the CEV System life cycle using FTH, Fault Tree Handbook with Aerospace Applications, August 2002, version 1.1 (Chapters 1-9), as guidance, and, shall document and deliver the results per **DRD CEV-S-002, Fault Tree Analysis**. The FTAs shall address hardware, software and human failures and shall be used to facilitate the hazard analyses.
- e) Reserved.
- f) The Contractor shall use Spacecraft Survivability Engineering (SSE) to address the design and implementation of opportunities to increase spacecraft survival to ensure all threats and hazard consequences to the completion of the mission are analyzed, and that all sources of uncertainty are identified and minimized. As part of SSE, Damage Modes and Effects Analysis (DMEA) shall be used to identify the vulnerabilities and areas where the spacecraft can incorporate robustness into the design and operation, and the results submitted as part of **DRD CEV-S-003**.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-S-002: Fault Tree Analysis
- DRD CEV-S-003: Flight System Safety Hazard Analysis
- DRD CEV-S-005: Ground System Safety Hazard Analysis

3.3 Industrial, Environmental, Processing Site, Launch Site and Range Safety

- a) The Contractor shall develop and deliver a mishap prevention plan per **DRD CEV-S-004, Mishap Plan and Safety Statistics**.
- b) The Contractor shall provide immediate verbal notification (upon discovery) and prompt written reporting (within 24 hours) to the NASA safety office and contracting officer of any accident, incident, or exposure resulting in fatality, lost-time occupational injury, disease, contamination of property beyond any stated acceptable limits, or property loss of \$1,000 or more. In addition, the Contractor shall provide mishap, close calls, and safety statistics

Crew Exploration Vehicle – (CEV)

Modification 904

including trend items per **DRD CEV-S-004**, *Mishap Plan and Safety Statistics*, and shall assist the NASA investigating authority, as requested, in investigating these incidents.

- c) Reserved
- d) Reserved
- e) The Contractor safety organization shall actively participate in Test Readiness Reviews to ensure personnel and hardware safety.
- f) The Contractor shall provide, in **DRD CEV-O-007** *Range Safety Requirements Documents*, safety and reliability data to support a range safety flight termination system (FTS) determination analysis per NPR 8715.5, Range Safety Program, and AFSPCMAN 91-710, Range Safety User Requirements Manual, or Range Commanders Council – Range Safety Group – 321-02 in accordance with the requirements in SOW Section 2.7.4, Range Safety Integration.
- g) The Contractor shall furnish a list of all hazardous operations to be performed and a list of key operations planned in the performance of the contract per **DRD CEV-S-006**, *Hazardous/Key Operations List*.
- h) The Contractor shall provide safety and reliability data to support the range safety analysis per **DRD CEV-S-003**, *System Safety Hazard Analysis*, and **DRD CEV-S-010**, *Probabilistic Risk Assessment Results*, to meet all local test range safety requirements.
- i) The Contractor shall coordinate with the CEV Project and the Constellation Program to develop and implement operational range safety requirements, plans, procedures, and check lists including mission rules and flight commit criteria, pertaining to Range Safety aspects of the CEV, in accordance with **DRD CEV-O-007**, *Range Safety Requirements Document*.
- j) The Contractor shall provide support to the joint Constellation Program and Air Force Eastern Range tailoring process for the integrated CEV/CLV and NPR 8715.5, Range Safety Program, with supporting technical expertise, analysis and requirements review to support CEV/CLV processing and launch.
- k) The Contractor shall provide technical expertise, supporting analysis and requirements review for the Constellation-led tailoring process of NPR 8715.5, Range Safety Program with respect to CEV entry and landing phases, in accordance with **DRD CEV-O-007**, *Range Safety Requirements Documents*.
- l) The Contractor shall perform an orbital debris assessment on the CEV system per **DRD CEV-S-007**, *Orbital Debris Assessment*, to determine the amount of orbital debris that may be generated both in nominal and malfunction operations and for collisions in orbit.
- m) The Contractor shall provide a safety and health program which identifies, eliminates, mitigates and controls hazards and risks in all Contractor activities and document the plan in **DRD CEV-S-008**, *Safety and Health Plan*.
- n) The Contractor and their subcontractors (if any) shall follow applicable OSHA, NASA, and CEV safety and health requirements. The Contractor and their subcontractors shall document this “flow down” of safety and health responsibility in the *Safety and Health Plan* (**DRD CEV-S-008**).
- o) The Contractor shall provide a debris catalog for the LAS to NASA to be used by the test range flight safety office to determine LAS debris impact areas.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- **DRD CEV-S-004**: Mishap Plan and Safety Statistics
- **DRD CEV-S-006**: Hazardous, Key Operations List

Crew Exploration Vehicle – (CEV)

Modification 994

- DRD CEV-S-007: Orbital Debris Assessment
- DRD CEV-S-008: Safety and Health Plan

The following Range Safety implementation specific data is collected in the DRD specified in Section 2.7.4

- DRD CEV-O-007: Range Safety Requirements Documents

3.4 Reliability, Maintainability, and Supportability (RMS)

- The Contractor shall develop, implement, and maintain an RMS Plan per **DRD CEV-S-001, Safety and Mission Assurance (S&MA) Plan**, which defines the implementation of RMS within their organization including processes, required skills, tasks and products for the CEV System.
- The Contractor shall perform Failure Modes Effects Analyses /Critical Items Lists (FMEA/CIL) per CxP-70043, Constellation Program Hardware Failure Modes and Effects Analysis and Critical Items List Methodology and document the results per **DRD CEV-S-009, Failure Mode and Effects Analysis & Critical Items List (FMEA/CIL)**. The Contractor shall establish and maintain the results in a common database that integrates the FMEA/CIL document, Hazard Analysis, Problem Reporting and Corrective Action (PRACA) data, Risk data and the Reliability Block Diagram Analysis. This common database shall provide the capability to interactively query, search, and sort the data to generate worksheet and index reports. These reports shall be used as part of the validation of the PRA models and R&M analysis used to show compliance to the CEV SRD requirements.
- The Contractor shall perform CEV System Probabilistic Risk Assessments for each Design Reference Mission as defined in CxP 70007, Constellation Design Reference Missions and Operational Concept, in support of risk-informed design. The PRAs will identify and prioritize the primary risk drivers and shall be conducted in accordance with CxP 70017. The results will be documented in **DRD CEV-S-010, Probabilistic Risk Assessment Results**. The Contractor shall also perform focused CEV PRAs to support necessary design trade studies or hazard analyses.
- The Contractor shall perform Reliability, Maintainability, and Supportability analyses for the reliability and maintainability requirements for the CEV System and shall document the results per the **DRD CEV-S-011, Reliability, Maintainability, and Supportability Integrated Report**. These results will be used to support the maintenance concept.
- The Contractor shall identify where Design for Minimum Risk (DFMR) is used in lieu of fault tolerance, where adding additional redundancy is not technically feasible or where redundancy would negatively impact overall system safety and reliability. The Contractor shall identify the rationale for acceptance of these DFMR functions designs. The Contractor shall document the above in **DRD CEV-S-011, Reliability, Maintainability, and Supportability Integrated Report**.
- The Contractor shall develop Reliability and Maintainability Planning Document(s) using the guidance of CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan.
- The Contractor shall participate in the GIDEP and NASA Alerts process employing **DRD CEV-S-012, Government-Industry Data Exchange Program and NASA Advisories/Alerts**.

Deliverables

The Contractor shall deliver and maintain the following document(s):

Crew Exploration Vehicle – (CEV)

Modification 994

- DRD CEV-S-009: Failure Modes Effects Analysis & Critical Items List (FMEA/CIL)
- DRD CEV-S-010: Probabilistic Risk Assessment Results
- DRD CEV-S-011: Reliability, Maintainability, and Supportability Integrated Report
- DRD CEV-S-012: Government-Industry Data Exchange Program and NASA Advisories/ALERTS

3.5 Hardware Quality Assurance

- a) The Contractor shall develop, implement and maintain a quality management system and Quality Assurance Plan per **DRD CEV-S-001**, *Safety and Mission Assurance (S&MA) Plan*, and in accordance with CXP-70059, Constellation Program Integrated Safety, Reliability & Quality Assurance (SR&QA) Requirements. The Quality Assurance Plan shall define their Quality Assurance organization including processes, required skills, tasks and products for the CEV project.
- b) The Contractor shall implement and document a Problem Reporting and Corrective Action (PRACA) system and provide all reportable problems, their status, and corrective actions, for both hardware and software in accordance with CxP 70068, Constellation Program Problem Reporting, Analysis and Corrective Action (PRACA) Requirements, Volumes 1, 2 and 3. PRACA Reports shall be delivered per **DRD CEV-S-013**, *Problem Reporting and Corrective Action (PRACA) Reports*.
- c) The Contractor shall identify, track, and disposition all hardware and software non-conformances, anomalies, and discrepancies in a Contractor database and provide NASA with access to these records, for the life of the Project.
- d) The Contractor shall perform internal and subcontractor audits per the *Safety and Mission Assurance (S&MA) Plan (DRD CEV-S-001)*. The Contractor shall document the findings and results of the internal and subcontractor audits per **DRD CEV-S-014**, *Quality Assurance Audit Reports*.
- e) The Contractor's S&MA organization shall review design specifications and designs to determine compliance with required materials specifications.
- f) The Contractor's S&MA organization shall review Materials and Special Processes activities in the CEV Spacecraft Manufacturing process, to ensure compliance with materials and process control specifications (including welding and brazing assurance, and NDE expertise to assure proper methods, techniques and standards are being used in the performance of NDE upon the hardware).
- g) The Contractor's S&MA organization shall participate in the Fracture Control Board for the CEV System to evaluate fracture-critical hardware.
- h) The Contractor shall document the controls for any process that cannot be verified by a reliable and repeatable inspection or test, and if not precisely applied and controlled within its defined limits, could result in hardware failure that results in loss of human life or serious injury/illness to the flight crew, ground crew, or general public; or results in loss of mission, or loss of a significant mission resource. These processes and their controls shall be documented in **DRD CEV-S-015**, *Critical Processes*.
- i) The Contractor shall develop, implement, and document a Mechanical Parts Assurance Plan for flight and critical ground support equipment hardware per **DRD CEV-S-016**, *Mechanical Parts Management and Implementation Plan*.
- j) The Contractor shall document its workmanship standards/specifications to ensure that they meet or exceed applicable NASA and Program Standards per **DRD CEV-S-017**, *Workmanship Standards*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-S-013: Problem Reporting and Corrective Action (PRACA) Reports
- DRD CEV-S-014: Quality Assurance (QA) Audit Report
- DRD CEV-S-015: Critical Processes
- DRD CEV-S-016: Mechanical Parts Management and Implementation Plan
- DRD CEV-S-017: Workmanship Standards

The following Quality Assurance Plan specific data is collected in the DRD specified in Section 3.1:

- DRD CEV-S-001: Safety and Mission Assurance Plan

3.6 Software Safety and Assurance

- a) The Contractor shall develop, implement, and maintain a Software Assurance Plan per **DRD CEV-S-001, Safety and Mission Assurance (S&MA) Plan, Chapter 6**.
- b) The Contractor shall demonstrate and document software assurance functions for all software in the CEV System in accordance with NASA-STD 8739.8 NASA Software Assurance Standard
 - Chapter 6, Provider Software Assurance
 - Chapter 7, Software Assurance Disciplines.
- c) The Contractor shall audit its own and any software suppliers internal software assurance activities to allow evaluation of both the progress and effectiveness of software assurance tasks and the need for adjustments or changes and document the results in **DRD CEV-S-018, Software Quality Assurance (SQA) Audit Reports**.
- d) The Contractor shall implement a systematic approach to software safety as an integral part of the project's overall system safety program, per **DRD CEV-S-001, Safety and Mission Assurance (S&MA) Plan, Chapter 2 - System Safety Plan**.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-S-018: Software Quality Assurance (SQA) Audit Report

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| Crew Exploration Vehicle – (CEV)

4 RESERVED

Attachment J-1

Modification ~~9~~⁹⁴

NNJ06TA25C

| Crew Exploration Vehicle – (CEV)

5 RESERVED

Attachment J-1

Modification ~~9~~⁹⁴

6 CEV SPACECRAFT DEVELOPMENT

Spacecraft development includes the tasks required for the design, development, production, assembly, test, and certification efforts to deliver the completed Spacecraft for integration with the launch vehicle and other mission elements.

6.1 Crew Module

The Crew Module includes the tasks required for the design, development, production, assembly, test, and certification of the Crew Module (CM) and efforts to deliver the completed Crew Module for Spacecraft integration.

6.1.1 CM Management and Administration

CM Management and Administration includes the efforts for planning, organizing, directing, coordinating, controlling, and approval processes used to accomplish Crew Module Development objectives.

- a) NASA will maintain detailed oversight of all Crew Module design activities. The Contractor shall maintain responsibility for delivery of a design that meets the requirements. The detailed process discussion to accomplish this can be found in CxP-72008, Crew Exploration Vehicle Project Plan. The Contractor shall include NASA personnel on all design teams established by the Contractor.

6.1.2 CM System Engineering and Integration

CM Systems Engineering and Integration consists of the efforts to lead the Crew Module's overall system architecture definition and engineering functions. This includes the technical and management efforts of directing and controlling the integrated engineering effort for the CM. This also includes the effort to coordinate CM integration with the CEV integration functions described in Section 2.

- a) The Contractor shall define the modules, subsystems, components, and software units that make up the Crew Module per the requirements and deliverables included in this section.
- b) The Contractor shall develop, maintain, and deliver all drawings and technical Computer Aided Design (CAD) models of the Crew Module system, subsystems and components. The Contractor shall use **DRD CEV-T-003**, *CEV CAD Models*, and **DRD CEV-T-004**, *CEV Drawings*, as the template for development and delivery of these items.
- c) The Contractor shall develop and maintain models and simulations for the Crew Module system, subsystems, and components using **DRD CEV-T-002**, *CEV Engineering Models*.
- d) The Contractor shall document ICD(s) for the government furnished products below:
 - o CEV Spacecraft docking components (APAS and LIDS) of the docking system for ISS and LSAM docking requirements
 - o Parachute system in support of nominal and abort entries
 - o Pyrotechnics initiators
- e) The Contractor shall document Crew Module subsystem requirements using **DRD CEV-T-031**, *CEV <Subsystem> Requirements Specifications*.
- f) The Contractor shall document component-level requirements within the Crew Module using **DRD CEV-T-031**, *CEV <Component> Requirements Specifications*.

Crew Exploration Vehicle – (CEV)

Modification 904

- g) The Contractor shall document all hardware interfaces requirements using **DRD CEV-T-035**, *Internal Interface Requirement Document (IRD)*. The Contractor shall produce an IRD for each subsystem that interfaces with another subsystem.
- h) The Contractor shall develop and maintain the Crew Module portion of the CEV Specification and Drawing Trees, **DRD-CEV-T-032**. The top drawing shall be incorporated into the CEV System Drawing Tree identified in Section 2.2.
- i) The contractor shall provide a CEV stowage interface design document in accordance with **DRD CEV-T-029**.
- j) The contractor shall document all Crew Module internal subsystem interface design details using **DRD CEV-T-029**, Interface Control Documents.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD-CEV-T-029: Crew Module Internal Interface Control Documents
- DRD CEV-T-029: Crew Module Internal<Subsystem> Interface Control Documents
- DRD CEV-T-029: Crew Module Internal Stowage Interface Control Documents

The following Module specific data is collected in the DRD specified in Section 2.2

- DRD CEV-T-031: Crew Module <Subsystem> Requirements Specifications
- DRD-CEV-T-031: Crew Module <Component> Requirements Specifications
- DRD CEV-T-032: CEV Specification and Drawing Tree for the Crew Module
- DRD CEV-T-035 Crew Module Internal Interface Requirements Documents

The following Module specific data is collected in the DRDs specified in Section 2.4

- DRD CEV-T-002: CM Engineering Models
- The following deliverables are separate Module deliverables and are integrated by reference into the System level submittal in 2.4.
- DRD CEV-T-003: CM CAD Models
- DRD CEV-T-004: CM Drawings

6.1.3 CM Subsystems

This Section includes the work required to design, develop, produce, and test through certification and acceptance all Crew Module subsystems required to meet CEV module-level and interface requirements.

- a) The Contractor shall design, develop, test, certify, and deliver Crew Module subsystem hardware complying with all requirements in CXP-72000, Systems Requirements for the Crew Exploration Vehicle Element (CEV SRD) (including the listed applicable documents and those included in this Statement of Work (SOW) See section 2.2).
- b) In support of the Crew Module avionics development effort, the Contractor shall provide the following for each subsystem:
 - o Validation of the subsystem's software requirements
 - o Validation of subsystem models/simulations used for flight software and integrated avionics verification
- c) The Contractor shall provide system and CM-level design definition data in the **DRD CEV-T-033**, *Architectural Design Document* and design definition and data down to the component level in the Subsystem Design and Data Books. (See Section 2.2)
- d) The Contractor shall hold subsystem design reviews prior to the system PDR and CDR.

Crew Exploration Vehicle – (CEV)

Modification 904

- e) The Contractor shall test (acceptance test only) and deliver flight spares for the Crew Module subsystems. (IDIQ) The Contractor shall provide a spare parts list as part of DRD-CEV-T-012 (See Section 2.7.2)
- f) The Contractor shall deliver Flight Spacecraft Crew Modules for **Orion 1 and Orion 2**.
- g) The Contractor shall deliver one ship set of Crew Module flight spares (i.e., 1 copy of every line replaceable unit) (IDIQ)
- h) The Contractor shall use the following standards and requirements documents for developing all CM subsystems:
 - o JPR 8080.5, JSC Design and Procedural Standards (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List) (exclusive of government "shalls")
 - o CXP-70024, Constellation Human Systems Integration Requirements (HSIR) (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List)
- i) The Contractor shall use the following standards for developing all CM subsystems:
 - o AIAA-S-080, AIAA Standard for Space Systems – Metallic Pressure Vessels Pressurized Structures, and Pressure Components
 - o ANSI/AIAA-S-081A-2006, AIAA Standard for Space Systems – Composite Overwrapped Pressure Vessels

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 2.7.2

- DRD CEV-T-012: Logistics Support Analysis

The following module specific information is collected in the DRDs specified in Section 2.2

- DRD CEV-T-033: Architecture Design Document

6.1.3.1 Reserved**6.1.3.2 CM Command & Data Handling**

- a) The Contractor shall document the design for all Crew Module C&DH hardware as specified in **DRD CEV-T-047, Avionics Design and Data Book Volume II - C&DH/Instrumentation Subsystem Data**.
- b) The Contractor shall deliver three ship sets of flight equivalent unit C&DH hardware (for the trainer).

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.1

- DRD CEV-T-047: Avionics Design and Data Book, Volume II – C&DH/Instrumentation Subsystem Data

6.1.3.3 *CM Communications & Tracking*

- a) For the Crew Module, the Contractor shall prepare, deliver, and maintain DRD CEV-T-047, Avionics Design and Data Book Volume III - Communications and Tracking Subsystem Data.
- b) The contractor shall provide the CEV to ISS CCA hardware and documentation necessary for CEV docking to ISS.
- c) The Contractor shall work with NASA on the integration of the CEV to ISS CCA hardware into the ISS.
- d) Any NASA provided components will be designed for environments consistent with ISS and Progress.

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.3

- DRD CEV-T-047: Avionics Design and Data Book, Volume III – Communications and Tracking Subsystem Data Book

6.1.3.4 *CM Displays and Controls*

- a) The Contractor shall prepare, maintain, and deliver Avionics Design and Data Book Volume IV - Displays and Controls Subsystem Data per **DRD CEV-T-047**.
- b) The Contractor shall deliver one ship set of flight equivalent unit D&C hardware (for the trainer).

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.4

- DRD CEV-T-047: Avionics Design and Data Book, Volume III – Displays and Controls Subsystem Data Book

6.1.3.5 *CM Electrical Power System*

- a) The Contractor shall document the design for all Crew Module EPS Hardware as specified in **DRD CEV-T-059, Electrical Power System (EPS) Design and Data Book**
- b) The Contractor shall participate with the Constellation Program in the development of DRD CEV-T-060, Electrical Power Quality Specification Requirements Document.

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.5

- DRD CEV-T-059: CM Electrical Power System (EPS) Design and Data Book
- DRD CEV-T-060: CM Electrical Power Quality Specification Requirements Document

6.1.3.6 CM Mechanisms

- a) NASA will provide the Androgynous Peripheral Assembly System (APAS) and associated data products as necessary to support ISS docking.
- b) The Contractor shall integrate ATLAS into the CEV Spacecraft configuration necessary to support specified ISS docking missions.
- c) NASA will provide the Low Impact Docking System (LIDS) and associated data products.
- d) The Contractor shall integrate LIDS into the CEV Spacecraft design as necessary to support ISS and Lunar docking.
- e) The Contractor shall document the design for all Crew Module mechanisms as specified in **DRD CEV-T-061**, *Mechanical Systems Design and Data Book*, and **DRD CEV-T-062**: *Stress Analysis Report*
- f) NASA will provide the CEV to ISS Docking Adapter for ISS docking.
- g) The Contractor shall integrate the CEV to ISS docking adapter for two adapter delivery missions to ISS. This integration includes NASA provided avionics required to operate Androgynous Peripheral Assembly Systems.
- h) The ISS CCA OSR's will be mounted such that they have a clear view to deep space.

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.6

- DRD CEV-T-061: CM Mechanical Systems Design and Data Book
- DRD CEV-T-062: CM Stress Analysis Report

6.1.3.7 CM Passive Thermal Control

- a) The Contractor shall develop thermal analytical models to support Crew Module thermal analyses.
- b) The Contractor shall document the design for all Crew Module Passive Thermal Control as specified in **DRD CEV-T-063**, *PTC Systems Design and Data Book*, and **DRD-CEV-T-064**, *Passive thermal Control Mathematical Models and Documentation*

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.7

- DRD CEV-T-063: CM Passive Thermal Control Design and Data Book (PTCDDDB)
- DRD CEV-T-064: CM Passive Thermal Control Mathematical Models and Documentation

6.1.3.8 CM Thermal Protection System

- a) NASA will perform advanced development of two designs for the TPS forebody heat shield component through the Orion PDR. The forebody heat shield component includes both the TPS materials or material system, the underlying support structure to which the TPS material is mounted, and the attachment or bonding agents or system. These two advanced development design options are as follows:
 - Primary Lunar Return capable

Crew Exploration Vehicle – (CEV)

Modification 904

- o Alternate Lunar Return capable
- b) NASA will produce the following subsystem products for PDR:
 - o TPS Component (Forebody Heatshield) Requirements Specification (**DRD CEV-T-031**)
 - o TPS Component (Forebody Heatshield) section of the *Thermal Protection System Design and Data Book (TPSDDDB)* (**DRD CEV-T-065**)
 - o TPS Component (Forebody Heatshield) Math Models as part of *Thermal Protection System Mathematical Models and Documentation* (**DRD CEV-T-066**) and *CEV CAD Models* (**DRD CEV-T-003**)
 - o Inputs to integrated Contractor products
- c) The contractor shall produce the following subsystem products post-transition:
 - o TPS Component (Forebody Heatshield) Requirements Specification (**DRD CEV-T-031**)
 - o TPS Component (Forebody Heatshield) section of the *Thermal Protection System Design and Data Book (TPSDDDB)* (**DRD CEV-T-065**)
 - o TPS Component (Forebody Heatshield) Math Models as part of *Thermal Protection System Mathematical Models and Documentation* (**DRD CEV-T-066**) and *CEV CAD Models* (**DRD CEV-T-003**)
- d) The Contractor shall participate in advanced development activities to the extent necessary to execute the efforts described in this SOW.
- e) The Contractor shall produce all remaining subsystem PDR products not produced by NASA.
- f) Following the TPS subsystem design review that occurs prior to Orion PDR, the Contractor shall perform detailed design, test, and analysis of the two TPS heat shield designs
- g) The Contractor shall establish a milestone for selecting one of the two TPS heat shield designs based on test and evaluation of the two designs. The Contractor shall recommend the TPS heat shield design to be used for final implementation at this milestone. The Contractor shall document this milestone in the Integrated Master Plan (IMP). NASA will select the final TPS heat shield design.
- h) The Contractor shall develop one engineering development unit (EDU) for the selected heat shield design for use in Contractor and NASA testing.
- i) The Contractor shall complete design, development, test, certification, and delivery of the selected TPS heat shield and all post-PDR DRD products.
- j) The Contractor shall design, develop, test, certify, and deliver all other CEV Spacecraft TPS components and DRD products.
- k) The Contractor shall develop thermal analytical models to support integrated Constellation vehicle analyses and CEV thermal analyses.
- l) NASA will lead, and the Contractor shall participate in, joint advanced development activities for the CEV thermal protection system through the Preliminary Design Review (PDR). The Contractor shall develop and implement plans, which detail the transition from development to insertion into the primary design path, for these advanced technologies. The Contractor shall document these plans in the design and data books for each subsystem.

Deliverables

- DRD CEV-T-065: Thermal Protection System Design and Data Book (TPSDDB)
- DRD CEV-T-066: Thermal Protection System Mathematical Models and Documentation

The following subsystem documentation is collected in the DRDs specified in Section 6.1.2, Post PDR

Crew Exploration Vehicle – (CEV)

Modification 994

- DRD CEV-T-031:CM Thermal Protection System <Subsystem> Requirements Specification
- DRD CEV-T-031: CM Thermal Protection System <Components> Requirements Specification

The following module specific information is collected in the DRDs specified in Section 2.4, Post PDR

- DRD CEV-T-002: CM TPS Engineering Models
- DRD CEV-T-003: CM TPS CAD Models
- DRD CEV-T-004: CM TPS Drawings

6.1.3.9 CM Structures

- The Contractor shall perform structural analysis on all Crew Module structures, including pressure vessels, to show that all elements of the design such as the strength, stiffness, structural stability, and life meet all specified criteria for the anticipated loads and environments.
- The Contractor shall perform Crew Module loads and dynamics analyses and document the results in **DRD CEV-T-067, Structural Loads Data Book**.
- The Contractor shall perform Crew Module stress and fatigue analyses and document the results in **DRD CEV-T-062, Stress Analysis Report**.
- The Contractor shall develop Crew Module models to support integrated Constellation vehicle analyses as well as CEV loads and stress analyses. The Contractor shall deliver **DRD CEV-T-068, Structures Mathematical Models and Documentation**, which will deliver and describe the mathematical models used in the Crew Module system, subsystem, and component loads and stress analyses.
- The Contractor shall implement a fracture control program and identify fracture critical parts to protect against catastrophic structural hazards associated with flaw presence, fatigue crack propagation and fracture. The Contractor shall deliver and implement **DRD CEV-T-069, Fracture Control Plan**, and **DRD CEV-T-070, Fracture Control Summary Report**.
- The Contractor shall use NASA-HDBK-7005, Dynamic Environmental Criteria, as a guidance document to support the **DRD CEV-T-015, Master Verification Plan** DRD product development activity.
- The Contractor shall use the following standards for designing and analyzing the Crew Module structures subsystem:
 - o Contract Attachment J-3, Table 1.2, Applicable Environmental Data Documents JSC-62550, Structural Design and Verification Criteria for Glass, Ceramics and Windows in Human Space Flight Applications
 - o NASA-STD-5001, Structural Design and Test Factors of Safety for Space Flight Hardware
 - o NASA-STD-5002, Loads Analyses of Spacecraft and Payloads
 - o NASA STD-(I)-5019, Fracture Control Requirements for Space Flight Hardware
- The contractor shall produce an engineering development Crew Module structure (Ground Test Article) for use in environmental testing. (See Section 2.6.9)
- The Contractor shall deliver a CM Structural Test Article (used for structural verification static and dynamic testing) via DD1149 process.

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.9

- DRD CEV-T-015 Master Verification Plan
- DRD CEV-T-062: CM Stress Analysis Report
- DRD CEV-T-067: CM Structural Loads Data Book
- DRD CEV-T-068: CM Structures Mathematical Models and Documentation
- DRD CEV-T-070: CM Fracture Control Summary Report

6.1.3.10 Crew Module Propulsion

- a) The Contractor shall perform design, development, test, certification and delivery of all Crew Module propulsion systems and develop all propulsion related DRD products.
- b) The Contractor shall develop, document, implement, and execute comprehensive verification activities and associated processes for all Crew Module propulsion systems in order to certify the propulsion systems for compliance with CEV component, subsystem, module, Spacecraft system, and vehicle-level requirements. The Contractor shall also design, fabricate and test integrated Crew Module propulsion systems in order to evaluate and certify integrated propulsion system hot fire performance for each propulsion application. The Contractor shall also design, fabricate, and test integrated Crew Module propulsion systems to evaluate and certify integrated propellant system storage and conditioning designs. (See Section 2.6.10)
- c) The Contractor shall document the design for all Crew Module propulsion as specified in DRD CEV-T-071, *Propulsion Systems Design and Data Book*.

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.10

- DRD CEV-T-071: CM Propulsion Systems Design and Data Book

6.1.3.11 Suits, EVA, and Survival Crew Equipment Support Systems

- a) NASA will provide the CEV suits and EVA support equipment per Orion to EVA Systems CEV IRD, CxP 70033 (e.g., EVA suits, launch and entry suits, helmets, gloves, undergarments, and standard EVA tools if applicable).
- b) NASA will provide portable crew equipment systems and gear as defined in CxP-70035 Portable Equipment, Payloads and Cargo IRD requirements for emergency egress and survival, crew/personnel post landing tracking systems, and crew/personnel post landing communications systems.
- c) The Contractor shall perform requirements development, design, analysis and trade studies, assembly/production, integration, testing, verification, validation, qualification, certification, and delivery of the CEV interfaces for the NASA-provided suits, EVA support equipment, and survival crew equipment as defined in CxP-70035 Portable Equipment, Payloads and Cargo IRD requirements.
- d) The Contractor shall provide specialized CEV-specific EVA tools, and external devices, restraints, and mobility aids.
- e) The Contractor shall use the human engineering standards listed in section 2.8.7, Human Engineering, to design all interfaces to suits, EVA, and survival crew equipment systems.

Crew Exploration Vehicle – (CEV)

Modification 904

- f) The contractor shall provide EVA handling aids mounted to the exterior of the ISS CCA to support installation, activation, and check out.
- g) NASA will provide the Vehicle Multiple Connector (MC) shipsets, and associated data products.
- h) The contractor shall support and integrate the NASA developed Vehicle Multiuse Connector.

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.11

- DRD CEV-T-072: CM Suits, EVA and Survival Crew Equipment Support Systems Design and Data Book

6.1.3.12 Crew Module Environmental Control and Life Support (ECLS), Crew Health and Habitation Accommodations

- a) NASA will provide food and food packaging. The Contractor shall design the Crew Module interfaces for these NASA-provided items.
- b) NASA will provide portable medical kits, equipment, and supplies, and portable countermeasures systems. The Contractor shall design the Crew Module interfaces for these NASA-provided items
- c) NASA will provide additional FCE such as personal hygiene kits, hygiene consumables, sleep restraints, portable supplemental lighting, portable vacuum cleaner, dust abatement system, disposable wipes, personal carry-on stowage, standard tools, crew clothing, and portable crew personal items (e.g., relaxation and entertainment systems). The Contractor shall design the Crew Module interfaces for these NASA-provided items.
- d) NASA will provide active and passive radiation instrumentation. The Contractor shall design the interfaces for these NASA-provided items.
- e) The Contractor shall use the following ECLS, crew health and habitation accommodations standards and the Human Engineering Standards listed in section 2.8.7, Human Engineering, for designing this subsystem:
 - o JSC 20584, Spacecraft Maximum Allowable Concentrations for Airborne Contaminants
- f) The Contractor shall provide definition of the process to be used for cleanliness of components for use in oxygen, fuel, and pneumatic systems. The Contractor shall provide this information in **DRD CEV-T-073, Environmental Control and Life Support Design and Data Book**. The process must meet or exceed the requirements identified in the following documents:
 - o MSFC-SPEC-164B, Specification for Cleanliness of Components for Use in Oxygen, Fuel and Pneumatic Systems (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List)
 - o MSFC-PROC-404, Gases, Drying and Preservation, Cleanliness Level and Inspection
 - o MSFC-PROC-1831, The Analysis of Nonvolatile Residue Content
 - o MSFC-PROC-1832, Sampling and Analysis of Nonvolatile Residue Content on Critical Surfaces

Crew Exploration Vehicle – (CEV)

Modification 904

- g) The Contractor shall identify the standard for test methods for environmental engineering in **DRD CEV-T-073**, *Environmental Control and Life Support Design and Data Book*. This standard shall meet or exceed the following standard:
- o MIL-STD-810F, DOD Test Method Standard for Environmental Engineering Considerations and Laboratory Tests, Section 5 and Part 2.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 2.6.12

- DRD CEV-T-073: CM Environmental Control and Life Support Design and Data Book
- DRD CEV-T-074: CM Habitation Accommodations Design and Data Book

6.1.3.13 CM Pyrotechnics

- a) The Contractor shall perform device level preliminary design reviews and critical design reviews for each Crew Module pyrotechnic devices not provided by NASA. The Contractor shall conduct development, qualification, and acceptance testing on all other pyrotechnic devices selected for the Crew Module. The Contractor shall conduct Phase I, Phase II, and Phase III technical reviews on all other pyrotechnic devices selected for the Crew Module per the requirements of JSC 62809, Constellation Spacecraft Pyrotechnic Specification and JPR 8080.5 Standards P1-P7.
- b) Crew Module specific stress analysis reports will be collected in the DRD (**DRD CEV-T-062**, *Stress Analysis Report*) specified in Section 2.6.13 for all pyrotechnic devices selected for the Crew Module.
- c) The Contractor shall document the design for the Crew Module pyrotechnic subsystem as specified in **DRD CEV-T-075**, *Pyrotechnic Subsystem Design and Data Book*
- d) NASA will supply pyrotechnic reefing line cutters used in the CPAS architecture

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following Module specific data is collected in the DRD specified in Section 2.4

- DRD CEV-T-002: CM Engineering Models
- DRD CEV-T-003: CM CAD Models
- DRD CEV-T-004: CM Drawings

The following Module specific data is collected in the DRD specified in Section 3.4

- DRD CEV-S-009 FEMA CIL

The following Module specific data is collected in the DRD specified in Section 2.8.4

- DRD CEV-T-022 MIUL

The following module specific information is collected in the DRDs specified in Section 2.6.13

- DRD CEV-T-062: CM Stress Analysis Report
- DRD CEV-T-075: CM Pyrotechnic Subsystem Design and Data Book

6.1.3.14 Landing and Recovery Systems

- a) NASA will provide the parachute system.
- b) The contractor shall provide the pyrotechnic devices with the exception of the reefing line cutters, and select Parachute Test Vehicle hardware (Parachute Bays and Forward Bay Covers) in support of the parachute system.
- c) NASA will perform advanced development of the landing attenuation system leading up to the landing attenuation subsystem design review.
- d) NASA will produce the following landing attenuation system PDR products that are derived from Landing and Recovery System Subsystem Requirements Specification (**DRD CEV-T-031**):
 - o Landing Attenuation System Subsystem Requirements Specification (**DRD CEV-T-031**, *CEV <Subsystem> Requirements Specification*)
 - o Landing Attenuation System Component Requirements Specification (**DRD CEV-T-031**, *CEV <Component> Requirements Specification*)
 - o Input to **DRD CEV-T-076**, Recovery Systems Design and Data Book
 - o Input to **DRD CEV-T-077**, Recovery Systems Simulation Models and Documentation
- e) The Contractor shall participate in the advanced development activities to the extent necessary to execute the efforts described in this SOW.
- f) The Contractor shall produce all remaining PDR products not produced by NASA.
- g) The Contractor shall complete design, development, test, certification, and delivery of the selected landing attenuation system and all post-PDR DRD products.
 - o Landing Attenuation System Subsystem Requirements Specification (**DRD CEV-T-031**, *CEV <Subsystem> Requirements Specification*)
 - o Landing Attenuation System Component Requirements Specification (**DRD CEV-T-031**, *CEV <Component> Requirements Specification*)
 - o **DRD CEV-T-076**, Recovery Systems Design and Data Book
 - o **DRD CEV-T-077**, Recovery Systems Simulation Models and Documentation
- h) The Contractor shall perform the requirements development, trade studies, design, analysis, production, assembly, integration, testing, verification, validation, qualification, certification, and maintenance for Contractor-provided CEV recovery hardware as specified by the CEV Project.
- i) The Contractor shall develop models and simulations for Contractor-provided hardware and integrate with the models and simulations for the NASA-provided hardware to support recovery systems development (**DRD CEV-T-077**, *Recovery System Simulation Models and Documentation*).
- j) NASA will lead, and the Contractor shall participate in, joint advanced development activities for the CEV landing attenuation through the system Preliminary Design Review (PDR). The Contractor shall develop and implement plans, which detail the transition from development to insertion into the primary design path, for these advanced technologies. The Contractor shall document these plans in the design and data books for each subsystem.
- k) The Contractor shall develop, implement, and maintain an Landing and recovery Systems Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of the Landing and Recovery System.

Deliverables

The Contractor shall deliver and maintain the following document(s):

Crew Exploration Vehicle – (CEV)

Modification 994

- DRD CEV-T-076: CM Recovery Systems Design and Data Book
- DRD CEV-T-077: CM Recovery Systems Simulation Models and Documentation

The following subsystem documentation is collected in the DRDs specified in Section 6.1.2, Post PDR

- DRD CEV-T-031: CM Landing Attenuation System <Subsystem> Requirements Specification
- DRD CEV-T-031: CM Landing Attenuation System <Components> Requirements Specification

The following module specific information is collected in the DRDs specified in Section 10.2, Post PDR

- DRD CEV-T-015: CM Recovery Systems Volume – Master Verification Plan

6.1.3.15 Crew Module Guidance, Navigation, and Control (GN&C)

- The Crew Module GN&C requirements design and functional verification effort will be performed through the use of specialized mode teams. NASA will co-lead with the Contractor the development of detailed design requirements for the Crew Module GN&C flight system. The Contractor shall document the Crew Module GN&C requirements in **DRD CEV-T-031, CEV GN&C Subsystem Requirements Specification**, and **DRD CEV-T-048, Software Requirements Specification**. The Contractor shall provide support to the following teams:
 - CEV Ascent/Abort Mode Team
 - Entry GN&C Mode Team
 - On-Orbit GN&C Mode Team
 - Flight Mechanics/Mission Design Mode Team
- The Contractor shall document the design for the Crew Module GN&C subsystem as specified in **DRD CEV-T-078, GN&C Systems Design and Data Book**.

Deliverables

The following module specific information is collected in the DRDs specified in Section 6.1.2

- DRD CEV-T-031: CM GN&C <Subsystem > Requirements Specification
- DRD CEV-T-031 CM GN&C <Components> Requirements Specification

The following module specific information is collected in the DRDs specified in Section 6.5.2

- DRD CEV-T-048: Software Requirements Specification

The following module specific information is collected in the DRDs specified in Section 2.6.15

- DRD CEV-T-078: CM GN&C Design and Data Book

6.1.3.16 CM Wiring

- The Contractor shall develop a wiring database that provides definition down to the level of pin-to-pin connectivity for all electrical harnesses and optical cables used on the Crew Module for ground, launch, flight, and recovery operations including testing, verification, calibration, and maintenance. The Contractor shall deliver the wiring database to NASA as **DRD CEV-T-080, CEV Wiring Database and Reports**. The Contractor shall provide a hierarchical path/signal structure which links the wiring database to **DRD CEV-T-046, CEV Data and Command Dictionary**.
- The Contractor shall develop, manufacture/fabricate, test, install, and certify all Crew Module wiring in accordance with **DRD CEV-T-079, CEV Wiring Plan**, and **DRD CEV-T-080, CEV Wiring Database and Reports**.

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.1

- DRD CEV-T-046: CEV Data and Command Dictionary

The following module specific information is collected in the DRDs specified in Section 2.6.16

- DRD CEV-T-079: CM Wiring Plan
- DRD CEV-T-080: CM Wiring Database and Reports

6.1.4 Reserved**6.1.5 CM Test, Verification, and Certification**

- a) The Contractor shall execute the Spacecraft Master Verification Plan for the verification, qualification, certification, and acceptance of the Crew Module, subsystems, and components.
- b) The Contractor shall perform qualification tests using **DRD CEV-T-037, Qualification Test Procedures**, and document the test results in **DRD CEV-T-038, Qualification Test Report**, and **DRD CEV-T-017, Certification Data Package**. The Contractor shall perform qualification testing at component, CM and intermediate levels of assembly as necessary to accumulate the data necessary for certification. The Contractor shall produce a Certification Data Package for the component, each subsystem in the Crew Module, the Crew Module, and the Spacecraft. Note: Software test documentation is handled in SOW section 6.5, CEV Software. The contractor shall develop a dedicated qualification Crew Module for system-level qualification testing. Following the completion of system-level qualification testing, the contractor shall maintain configuration control of the dedicated qualification CM and store it in an environmentally-controlled and access-controlled area.
- c) The Contractor shall perform acceptance testing at the Crew Module and CM component level using **DRD CEV-T-039, Acceptance Test Procedures**, and document the results using **DRD CEV-T-040, Acceptance Data Package**. An Acceptance Data Package shall be produced for the production flight Crew Modules (Orion 1 and 2).
- d) The Contractor shall hold Test Readiness Reviews (TRRs) before all formal verification activities. The Contractor shall make subsystem and module test procedures available to NASA. The Contractor shall invite NASA, to witness all formal verification activities, including TRRs and test executions.
- e) The Contractor shall conduct verification testing of all interface designs and requirements within the Crew Module (between subsystems, and between components).
- f) If the Contractor utilizes modeling and simulation to conduct analysis in support of verification specification compliance, the Contractor shall comply with **DRD CEV-T-001, Integrated Models, Simulations and Support Plan**, and **DRD CEV-T-002, CEV Engineering Models**.
- g) The Contractor shall provide the integration, test, & verification facilities required to test and certify the Crew Module and all CM subsystems and components. The Contractor shall invite NASA to witness all subsystem facility design reviews, test, verification, and certification activities.
- h) The Contractor shall provide the Integration, Test, & Verification (IT&V) facilities required to complete integrated verification of the Crew Module. The requirements for the IT&V facilities shall be derived from the products developed under Section 10.1, Test, Verification Management and Administration.

Crew Exploration Vehicle – (CEV)

Modification 994

- i) The Contractor shall develop, implement, and maintain an CM Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of Crew module.
- j) The Contractor shall provide support in order to conduct verification testing of all interface designs and requirements within the CM Module for those verification activities that are NASA led in NASA facilities.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 10.2:

- DRD-CEV-T-015: Crew Module Volumn Master Verification Plan

The Contractor shall deliver the following DRDs for the Qualification Vehicle CM, incorporating all lower level element Qualification data. These DRDs will be also collected into the DRD specified in Sections 10.2 and 10.3 for the integrated CEV.

- DRD CEV-T-017 Certification Data Package
- DRD CEV-T-037: Qualification Test Procedures
- DRD CEV-T-038: Qualification Test Report

The Contractor shall deliver the following DRDs for the Production Vehicle CM, incorporating all lower level element acceptance data. These DRDs will be also collected into the DRD specified in Sections 10.2 and 10.3 for the integrated CEV.

- DRD CEV-T-039: Acceptance Test Procedures
- DRD CEV-T-040: Acceptance Data Package

6.1.6 CM Assembly, Integration, and Production (AI&P)

- a) The Contractor shall integrate, assemble, certify, acceptance test, and deliver flight Crew Modules meeting the requirements for the configurations below.
- b) The Contractor shall develop and implement an imagery plan to provide imagery (e. g., still photo, motion picture, digital imagery, or video) of the Crew Module, subsystems, and components during manufacturing, assembly, test, integration, and close-out to document the hardware configuration. The Contractor shall include the plan and imagery in **DRD CEV-T-088**, *CEV Imagery Plan/Imagery Deliverables*.
- c) The Contractor shall develop and implement plans detailing the design and construction of all Crew Module transportation support equipment, and the plans for transportation of the Crew Module to the processing and/or launch sites. These plans shall be included in **DRD CEV-T-087**, *CEV Spacecraft Handling and Transportation Plan*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 2.7.2:

- DRD CEV-T-087: CEV Handling and Transportation Plan

The following module specific information is collected in the DRDs specified in Section 2.10:

- DRD CEV-T-086: Manufacturing and Assembly Plan
- DRD CEV-T-088: CEV Imagery Plan/Imagery Deliverables

6.1.6.1 CM Flight Hardware AI&P

- a) The Contractor shall integrate, assemble, certify, acceptance test, and deliver flight Crew Modules meeting the requirements for configurations below.
- b) The Contractor shall develop and implement plans detailing the design and construction of all Crew Module transportation support equipment, and the plans for transportation of the Crew Module to the processing and/or launch sites. These plans shall be included in **DRD CEV-T-087, CEV Spacecraft Handling and Transportation Plan**.
- c) The Contractor shall deliver a production CM for Orion 1 and a production CM for Orion 2.
- d) The Contractor shall be responsible for post-flight refurbishment of any reusable items delivered under Schedule A. (IDIQ)
- e) The Contractor shall design, develop, produce, integrate, verify, validate, certify, document, and deliver Crew Module GSE in accordance with all requirements in CXP-72000, Systems Requirements for the Crew Exploration Vehicle Element (CEV SRD), and in this SOW, and in accordance with **DRD CEV-O-008, Ground Systems Requirements, Plans, Reports, and Design Data, Volume II, Ground Systems End Item Implementation Plan and Report**. The Contractor shall plan for and deliver the GSE end items in accordance with Attachment J-9. The Contractor shall use the following applicable documents for design and development of Contractor-provided GSE:
 - o NASA-STD-5005B: NASA Standard for Ground Support Equipment (and associated Applicable Document Children as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List).
- f) The Contractor shall develop and update **DRD CEV-O-008, Ground Systems Requirements, Plans, Reports, and Design Data, Volume III, Systems Operations and Maintenance Plan and Requirements Documentation**, for the ground support equipment provided for the Crew Module.
- g) The Contractor shall develop, maintain and deliver all technical models and drawings of the GSE associated with the Crew Module in accordance with **DRD CEV-T-003, CEV CAD Models**, and **DRD CEV-T-004, CEV Drawings**.
- h) The Contractor shall develop and update 2-D and 3-D simulation models of the Contractor-provided Crew Module and Contractor-provided Crew Module GSE to assess clearances, placement, conflicts and the moving of hardware in accordance with **DRD CEV-T-003, CEV CAD Models**. The Contractor shall develop and deliver these models in accordance with SOW Section 2.4.
- i) The Contractor shall develop and deliver **DRD CEV-T-040, Acceptance Data Package**, for each Contractor-provided Crew Module GSE end item.
- j) The Contractor shall provide initial spares, concurrent with the delivery of the GSE end items and in accordance with the provisioning procedures in **DRD CEV-T-011, Integrated Logistics Support Plan**, and **DRD CEV-T-012, Logistics Support Analysis**, for all Contractor-provided Crew Module GSE. (IDIQ)
- k) (reserved)
- l) The Contractor shall integrate, assemble, certify, acceptance test, and deliver flight hardware, for installation to the ISS meeting the requirements of CEV and the environments/requirements of ISS in accordance with the CEV to ISS IRD.
- m) ISS CCA qualification and acceptance testing will be conducted at the assembly level.

Crew Exploration Vehicle – (CEV)

Modification 904

- n) For Orion 1, the Government shall provide a Developmental Flight Instrumentation (DFI) system and installation engineering, installed by the Contractor.

o)

Deliverables

The following CM GSE data is incorporated in the DRD specified in Section 2.4:

- DRD CEV-T-003: CEV CAD Models
- DRD CEV-T-004: CEV Drawings

The following CM GSE data is incorporated in the DRD specified in Section 2.7.2:

- DRD CEV-O-008: Ground Systems Requirements, Plans, Reports, and Design Data
- DRD CEV-T-040: Acceptance Data Package
- DRD CEV-T-087: CEV Handling and Transportation Plan

6.1.6.2 Test Article Design and Production

- a) The CM primary structure for PA1 and AA1 will be provided by NASA
- b) For PA1 and AA1, the Contractor shall design, develop, procure, build, assemble, integrate, and verify the CM avionics and mechanisms kits per the requirements and specifications developed in Section 10.6.4, Flight Test Article (FTA) DDT&E.
- c) RESERVED
- d) For PA2, and AA2, the Contractor shall design and develop the prototype CMs using the system, module, sub-system, and component level requirements and specifications developed in section 10.6.4, Flight Test Article (FTA) DDT&E; documented in **DRD CEV-D-002, Flight Test Article <Level> Specification**.
- e) For PA2, and AA2, the Contractor shall procure, build, assemble, integrate, and test the prototype CMs under this section of the SOW. Prototype FTAs must meet the production standards as specified in section 10.6.4, FTA DDT&E, paragraph u; documented in **DRD CEV-D-004, Flight Test Article (FTA) Design and Data Book**.
- f) For PA2, and AA2, the Contractor shall validate and verify the flight test unique design as specified in CEV- T-015, Volume VII, Master Verification Plan, Flight Test Volume and documented in accordance with section 10.6.4, FTA DDT&E, paragraph y x;
- g) For PA2, and AA2, the Contractor shall deliver three (3) two (2) prototype CMs. (+ DD250 for each CM).
- h) For Ares-1Y2 the Contractor shall deliver one production like CM with elements removed (and replaced with simulators) that are not required to meet mission objectives defined in CXP-72166.
- i) The Contractor shall design, develop, produce, integrate, verify, validate, certify, document, and deliver CM FTA GSE in accordance with all requirements in CXP 72000, Systems Requirements for the Crew Exploration Vehicle Element (CEV SRD), and in this SOW, and in accordance with **DRD CEV-O-008, Ground Systems Requirements, Plans, Reports, and Design Data, Volume II, Ground Systems End Item Implementation Plan and Report**. The Contractor shall use the following applicable documents for design and development of Contractor-provided GSE:
- o NASA-STD-5005B: NASA Standard for Ground Support Equipment (and associated Applicable Document Children as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List).
- j) The Contractor shall deliver a CM test article for a Ground Vibration Test at MSFC in accordance with CxP 72234, Integrated Vehicle Ground Vibration Test Task Plan. This CM

Crew Exploration Vehicle – (CEV)

Modification 904

test article can either be simulated modules or residual test articles refurbished to support specific requirements of the test. Support for Integrated Vehicle Ground Vibration Test shall be in accordance with the Ares IVGVT & Orion Bilateral Exchange Agreement (BEA).

- k) The Contractor shall develop **DRD-CEV-T-031**, *CEV FTA Requirements Specification* for Flight Tests Ares 1-Y as defined in Section 10.6.4.
- l) The Contractor shall develop and maintain **DRD CEV-D-005**, Flight Test Article (FTA) Validation and Verification Data Book, identified in Section 10.6, for the CM FTA.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following CM FTA data is incorporated in the DRD specified in Section 10.2:

DRD-CEV-T-015: FTA Volume Master Verification Plan (per Section 10.6)

The following Module specific information is collected in the DRDs specified in Section 10.6.4:

- DRD CEV-D-002: Flight Test Article <Level> Specification for Pad Abort and Ascent Abort Flight Tests.
- DRD CEV-D-004: Flight Test Article (FTA) Engineering Design and Data Book
- DRD CEV-D-005: Flight Test Article (FTA) Validation and Verification Data Book
- DRD CEV-T-031: CEV <Level> Requirements Specification, for the Flight Test Articles for Ares 1Y

The following Module specific information is collected in the DRDs specified in Section 2.7.2

- DRD CEV-O-008: Ground Systems Requirements, Plans, Reports, and Design Data, Volume II, Ground Systems End Item Implementation Plan and Report.

6.2 Service Module

Service Module (which includes the Spacecraft Adapter) includes the tasks required for the design, development, production, assembly, test, and certification of the Service Module, and efforts to deliver the completed SM for Spacecraft integration.

6.2.1 SM Management and Administration

SM Management and Administration includes the efforts for planning, organizing, directing, coordinating, controlling, and approval processes used to accomplish Service Module development objectives.

- a) NASA will maintain detailed oversight of all Service Module design activities. The Contractor shall maintain responsibility for delivery of a design that meets the requirements. The detailed process discussion to accomplish this can be found in CxP-72008, Crew Exploration Vehicle Project Plan. The Contractor shall include NASA personnel on all design teams established by the Contractor.

6.2.2 SM System Engineering and Integration

SM Systems Engineering and Integration consist of the efforts to lead the Service Module's overall system architecture definition and engineering functions. This includes the technical and management efforts of directing and controlling the integrated engineering effort for the SM. This also includes the effort to coordinate SM integration with the CEV integration functions described in Section 2.

Crew Exploration Vehicle – (CEV)

Modification 904

- a) The Contractor shall define the modules, subsystems, components, and software units that make up the Service Module per the requirements of this section.
- b) The Contractor shall define the modules, subsystems, components, and software units that make up the Service Module per the requirements and deliverables included in this section.
- c) The Contractor shall develop, maintain, and deliver all drawings and technical Computer Aided Design (CAD) models of the Service Module system, subsystems and components. The Contractor shall use **DRD CEV-T-003**, *CEV CAD Models*, and **DRD CEV-T-004**, *CEV Drawings*, as the template for development and delivery of these items.
- d) The Contractor shall develop and maintain models and simulations for the Service Module system, subsystems, and components using **DRD CEV-T-002**, *CEV Engineering Models*.
- e) The Contractor shall document and maintain ICD(s) for the government furnished products below:
 - o Pyrotechnics initiators
- f) The Contractor shall document Service Module- level requirements using **DRD CEV-T-031**, *CEV <Subsystem> Requirements Specifications*.
- g) The Contractor shall document component-level requirements within the Service Module using **DRD CEV-T-031**, *CEV <Component> Requirements Specifications*.
- h) The Contractor shall document all hardware interfaces requirements using **DRD CEV-T-035**, *Internal Interface Requirement Document (IRD)*. The Contractor shall produce an IRD for each subsystem that interfaces with another subsystem.
- i) The Contractor shall develop and maintain the Service Module portion of the CEV Specification and Drawing Trees, **DRD-CEV-T-032**. The top drawing shall be incorporated into the CEV System Drawing Tree identified in Section 2.2
- j) The contractor shall document all Service Module internal subsystem interface design details using **DRD CEV-T-029**, *Interface Control Documents*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD-CEV-T-029: Service Module Internal Interface Control Documents
- DRD CEV-T-031: Service Module <Subsystem> Requirements Specifications
- DRD-CEV-T-031: Service Module <Component> Requirements Specifications
- DRD CEV-T-032: CEV Specification and Drawing Tree for the Service Module and Spacecraft Adapter
- DRD CEV-T-035 Service Module Internal Interface Requirements Documents

The following Module specific data is collected in the DRDs specified in Section 2-4 3

- DRD CEV-T-002: SM Engineering Models
- The following deliverables are separate Module deliverables and are integrated by reference into the System level submittal in 2.3.
- DRD CEV-T-003: SM CAD Models
- DRD CEV-T-004: CM Drawings

6.2.3 SM Subsystems

This section includes the work required to design, develop, produce, and test through certification and acceptance all Service Module subsystems required to meet CEV module-level and interface requirements. Spacecraft Adapter Subsystems deliverables will be developed as appropriate.

Crew Exploration Vehicle – (CEV)

Modification 904

- a) The Contractor shall design, develop, test, certify, and deliver Service Module subsystem hardware complying with all requirements in CXP-72000, Systems Requirements for the Crew Exploration Vehicle Element (CEV SRD) (including the listed applicable documents and those included in this Statement of Work (SOW) See Section 2.2).
- b) In support of the Service Module avionics development effort, the Contractor shall provide the following for each subsystem:
 - o Validation of the subsystem's software requirements
 - o Validation of subsystem models/simulations used for flight software and integrated avionics verification
- c) The Contractor shall provide system and LAS-level design definition data in the **DRD CEV-T-033, Architectural Design Document** and design definition and data down to the component level in the Subsystem Design and Data Books.
- d) The Contractor shall hold subsystem design reviews prior to the system PDR and CDR.
- e) The Contractor shall test (acceptance test only) and deliver flight spares for the Service Module subsystems. The Contractor shall provide a spare parts list as part of the **DRD CEV-T-012, Logistics Support Analysis (Recommended Spare Parts List)**. (IDIQ)
- f) The Contractor shall deliver 1 Flight Spacecraft Service Module (including the Spacecraft Adapter) for Orion 1 and 1 Flight Spacecraft Service Module for Orion 2.
- g) The Contractor shall deliver one ship set of Service Module flight spares (i.e., 1 copy of every line replaceable unit) (IDIQ)
- h) The Contractor shall use the following standards and requirements documents for developing all SM subsystems:
 - o JPR 8080.5, JSC Design and Procedural Standards (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List) (exclusive of government "shalls")
 - o CXP-70024, Constellation Human Systems Integration Requirements (HSIR) (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List)
- i) The Contractor shall use the following standards for developing all SM and SA subsystems:
 - o AIAA-S-080, AIAA Standard for Space Systems – Metallic Pressure Vessels Pressurized Structures, and Pressure Components
 - o ANSI/AIAA-S-081A-2006, AIAA Standard for Space Systems – Composite Overwrapped Pressure Vessels

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 2.7.2

- DRD CEV-T-012: Logistics Support Analysis

The following module specific information is collected in the DRDs specified in Section 2.2

- DRD CEV-T-033: Architecture Design Document

6.2.3.1 *Reserved*

6.2.3.2 *SM Command and Data Handling (C&DH)*

- a) The Contractor shall document the design for all Service Module C&DH hardware as specified in **DRD CEV-T-047**, *Avionics Design and Data Book Volume II - C&DH/Instrumentation Subsystem Data*.

Deliverables

The Contractor shall deliver and maintain the following document(s) as applicable:

- DRD CEV-T-047: Avionics Design and Data Book, Volume II – C&DH/Instrumentation Subsystem Data

6.2.3.3 *SM Communications and Tracking (C&T)*

- a) For the Service Module, the Contractor shall prepare, deliver, and maintain DRD CEV-T-047, Avionics Design and Data Book Volume III - Communications and Tracking Subsystem Data.

Deliverables

The Contractor shall deliver and maintain the following document(s) as applicable:

The following module specific information is collected in the DRDs specified in Section 2.6.3

- DRD CEV-T-047: Avionics Design and Data Book, Volume III – Communications and Tracking Subsystem Data Book

6.2.3.4 *Reserved*

6.2.3.5 *SM Electrical Power System*

- a) The Contractor shall document the design for all Service Module EPS Hardware as specified in **DRD CEV-T-059**, *Electrical Power System (EPS) Design and Data Book*
- b) The Contractor shall participate with the Constellation Program in the development of DRD CEV-T-060, Electrical Power Quality Specification Requirements Document.

Deliverables

The Contractor shall deliver and maintain the following document(s) as applicable:

The following module specific information is collected in the DRDs specified in Section 2.6.5

- DRD CEV-T-059: SM Electrical Power System (EPS) Design and Data Book
- DRD CEV-T-060: SM Electrical Power Quality Specification Requirements Document

6.2.3.6 SM Mechanisms

- a) The Contractor shall document the design for all Service Module mechanisms as specified in **DRD CEV-T-061**, *Mechanical Systems Design and Data Book*, and **DRD CEV-T-062**: *Stress Analysis Report*

Deliverables

The Contractor shall deliver and maintain the following document(s) as applicable:

The following module specific information is collected in the DRDs specified in Section 2.6.6

- DRD CEV-T-061: SM Mechanical Systems Design and Data Book
- DRD CEV-T-062: SM Stress Analysis Report

6.2.3.7 SM Passive Thermal Control

- a) The Contractor shall develop thermal analytical models to support Service Module thermal analyses.
- b) The Contractor shall document the design for all Service Module Passive Thermal Control as specified in **DRD CEV-T-063**, *PTC Systems Design and Data Book*, and **DRD-CEV-T-064**, *Passive thermal Control Mathematical Models and Documentation*

Deliverables

The Contractor shall deliver and maintain the following document(s) as applicable:

The following module specific information is collected in the DRDs specified in Section 2.6.7

- DRD CEV-T-063: SM Passive Thermal Control Design and Data Book (PTCDDDB)
- DRD CEV-T-064: SM Passive Thermal Control Mathematical Models and Documentation

6.2.3.8 Reserved

6.2.3.9 SM Structures

- a) The Contractor shall perform structural analysis on all Service Module structures, including pressure vessels, to show that all elements of the design such as the strength, stiffness, structural stability, and life meet all specified criteria for the anticipated loads and environments.
- b) The Contractor shall perform Service Module loads and dynamics analyses and document the results in **DRD CEV-T-067**, *Structural Loads Data Book*.
- c) The Contractor shall perform Service Module stress and fatigue analyses and document the results in **DRD CEV-T-062**, *Stress Analysis Report*.
- d) The Contractor shall develop Service Module models to support integrated Constellation vehicle analyses as well as CEV loads and stress analyses. The Contractor shall deliver **DRD CEV-T-068**, *Structures Mathematical Models and Documentation*, which will deliver and describe the mathematical models used in the Service Module system, subsystem, and component loads and stress analyses.

Crew Exploration Vehicle – (CEV)

Modification 994

- e) The Contractor shall implement a fracture control program and identify fracture critical parts to protect against catastrophic structural hazards associated with flaw presence, fatigue crack propagation and fracture. The Contractor shall deliver and implement **DRD CEV-T-069**, *Fracture Control Plan*, and **DRD CEV-T-070**, *Fracture Control Summary Report*.
- f) The Contractor shall use NASA-HDBK-7005, Dynamic Environmental Criteria, as a guidance document to support the **DRD CEV-T-015**, *Master Verification Plan* DRD product development activity.
- g) The Contractor shall use the following standards for designing and analyzing the Service Module structures subsystem:
 - o CXP-15002, Crew Exploration Vehicle (CEV)/Crew Launch Vehicle (CLV) Loads Requirements Data Book
 - o JSC-62550, Structural Design and Verification Criteria for Glass, Ceramics and Windows in Human Space Flight Applications
 - o NASA-STD-5001, Structural Design and Test Factors of Safety for Space Flight Hardware
 - o NASA-STD-5002, Loads Analyses of Spacecraft and Payloads
 - o NASA STD-(I)-5019, Fracture Control Requirements for Space Flight Hardware
- h) The contractor shall produce an engineering development Service Module structure for use in environmental testing (Ground Test Article). (See Section 2.6.9)
- i) The Contractor shall deliver an SM Structural Test Article (used for structural verification static and dynamic testing), via DD1149 process.

Deliverables

The Contractor shall deliver and maintain the following document(s) as applicable:

The following module specific information is collected in the DRDs specified in Section 2.6.9

- DRD CEV-T-062: SM Stress Analysis Report
- DRD CEV-T-067: SM Structural Loads Data Book
- DRD CEV-T-068: SM Structures Mathematical Models and Documentation
- DRD CEV-T-070: SM Fracture Control Summary Report
- DRD CEV-T-015: Structures Subsystem Volume Master Verification Plan

6.2.3.10 SM Propulsion

- a) The Contractor shall perform design, development, test, certification and delivery of all Service Module propulsion systems and develop all propulsion related DRD products.
- b) The Contractor shall develop, document, implement, and execute comprehensive verification activities and associated processes for all Service Module propulsion systems in order to certify the propulsion systems for compliance with CEV component, subsystem, module, Spacecraft system, and vehicle-level requirements. The Contractor shall also design, fabricate and test integrated Service Module propulsion systems in order to evaluate and certify integrated propulsion system hot fire performance for each propulsion application. The Contractor shall also design, fabricate, and test integrated Service Module propulsion system to evaluate and certify integrated propellant system storage and conditioning designs and capabilities in order to evaluate and certify propellant conditioning performances. (See Section 2.6.10)
- c) The contractor shall incorporate single-fault tolerance into the bipropellant valves and pneumatic system of the CEV Service Module main engine.

- d) The Contractor shall document the design for all Service Module propulsion as specified in **DRD CEV-T-071**, *Propulsion Systems Design and Data Book*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-071: SM Propulsion Systems Design and Data Book

6.2.3.11 Suits, EVA, and Survival Crew Equipment Support Systems

- a) The Contractor shall provide specialized CEV-specific EVA tools, and external devices, restraints, and mobility aids as necessary in the Service Module design.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 2.6.11

- DRD CEV-T-072: EVA and Survival Crew Equipment Support Systems Design and Data Book

6.2.3.12 Service Module and Spacecraft Adapter Environmental Control and Life Support (ECLS), Crew Health and Habitation Accommodations

- a) The Contractor shall use the following ECLS, standards and the Human Engineering Standards listed in section 2.8.7, Human Engineering, for designing this subsystem:
- JSC 20584, Spacecraft Maximum Allowable Concentrations for Airborne Contaminants
- b) The Contractor shall provide definition of the process to be used for cleanliness of components for use in oxygen, fuel, and pneumatic systems. The Contractor shall provide this information in **DRD CEV-T-073**, *Environmental Control and Life Support Design and Data Book*. The process must meet or exceed the requirements identified in the following documents:
- MSFC-SPEC-164B, Specification for Cleanliness of Components for Use in Oxygen, Fuel and Pneumatic Systems (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List)
 - MSFC-PROC-404, Gases, Drying and Preservation, Cleanliness Level and Inspection
 - MSFC-PROC-1831, The Analysis of Nonvolatile Residue Content
 - MSFC-PROC-1832, Sampling and Analysis of Nonvolatile Residue Content on Critical Surfaces
- c) The Contractor shall identify the standard for test methods for environmental engineering in **DRD CEV-T-073**, *Environmental Control and Life Support Design and Data Book*. This standard shall meet or exceed the following standard:
- MIL-STD-810F, DOD Test Method Standard for Environmental Engineering Considerations and Laboratory Tests, Section 5 and Part 2.

Deliverables

The Contractor shall deliver and maintain the following document(s):

Crew Exploration Vehicle – (CEV)

Modification 904

- The following module specific information is collected in the DRDs specified in Section 2.6.12:
- DRD CEV-T-073: Environmental Control and Life Support Design and Data Book

6.2.3.13 SM Pyrotechnics

- The Contractor shall perform device level preliminary design reviews and critical design reviews- for each Service Module pyrotechnic device not provided by NASA. The Contractor shall conduct development, qualification, and acceptance testing on all other pyrotechnic devices selected for the Service Module. The Contractor shall conduct Phase I, Phase II, and Phase III technical reviews on all other pyrotechnic devices selected for the Service Module per the requirements of JSC 62809, Constellation Spacecraft Pyrotechnic Specification and JPR 8080.5 Standards P1-P7.
- Service Module specific stress analysis reports will be collected in the DRD (**DRD CEV-T-062, Stress Analysis Report**) specified in Section 2.6.13 for all pyrotechnic devices selected for the Service Module.
- The Contractor shall document the design for the Service Module Module pyrotechnic subsystem as specified in DRD CEV-T-075, Pyrotechnic Subsystem Design and Data Book

Deliverables

The Contractor shall deliver and maintain the following document(s) as applicable: The following module specific information is collected in the DRDs specified in Section 2.4

- DRD CEV-T-002: SM Engineering Models
- DRD CEV-T-003: SM CAD Models
- DRD CEV-T-004: SM Drawings

The following Module specific data is collected in the DRD specified in Section 3.4

- DRD CEV-S-009 FMEA CIL

The following Module specific data is collected in the DRD specified in Section 2.8.4

- DRD CEV-T-022 MIUL

The following module specific information is collected in the DRDs specified in Section 2.6.13

- DRD CEV-T-062: SM Stress Analysis Report
- DRD CEV-T-075: SM Pyrotechnic Subsystem Design and Data Book

6.2.3.14 Reserved

6.2.3.15 SM Guidance, Navigation, and Control (GN&C)

- The Service Module GN&C requirements design and functional verification effort will be performed through the use of specialized mode teams. NASA **will co-lead with** the Contractor the development of detailed design requirements for the Service Module GN&C flight system. The Contractor shall document the Service Module and Spacecraft Adapter GN&C requirements in **DRD CEV-T-031, CEV GN&C Subsystem Requirements Specification**, and **DRD CEV-T-048, Software Requirements Specification**. The Contractor shall provide support to the following teams:
 - CEV Ascent/Abort Mode Team
 - On-Orbit GN&C Mode Team

Crew Exploration Vehicle – (CEV)

Modification 994

- o Flight Mechanics/Mission Design Mode Team
- b) The Contractor shall document the design for the Service Module GN&C subsystem as specified in **DRD CEV-T-078**, GN&C Systems Design and Data Book.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 6.1.2:

- DRD CEV-T-031: SM GN&C <Subsystem > Requirements Specification
- DRD CEV-T-031 SM GN&C <Components> Requirements Specification

The following module specific information is collected in the DRDs specified in Section 6.5.2:

- DRD CEV-T-048: Software Requirements Specification

The following module specific information is collected in the DRDs specified in Section 2.6.15:

- DRD CEV-T-078: SM GN&C Design and Data Book

6.2.3.16 SM Wiring

- a) The Contractor shall develop a wiring database that provides definition down to the level of pin-to-pin connectivity for all electrical harnesses and optical cables used on the Service Module for ground, launch, flight, and recovery operations including testing, verification, calibration, and maintenance. The Contractor shall deliver the wiring database to NASA as **DRD CEV-T-080**, *CEV Wiring Database and Reports*. The Contractor shall provide a hierarchical path/signal structure which links the wiring database to **DRD CEV-T-046**, *CEV Data and Command Dictionary*.
- b) The Contractor shall develop, manufacture/fabricate, test, install, and certify all Service Module wiring in accordance with **DRD CEV-T-079**, *CEV Wiring Plan* and **DRD CEV-T-080**, *CEV Wiring Database and Reports*.

Deliverables

The Contractor shall deliver and maintain the following document(s) as applicable:

The following module specific information is collected in the DRDs specified in Section 2.6.1

- DRD CEV-T-046: CEV Data and Command Dictionary

The following module specific information is collected in the DRDs specified in Section 2.6.16

- DRD CEV-T-079: SM Wiring Plan
- DRD CEV-T-080: SM Wiring Database and Reports

6.2.4 Reserved**6.2.5 SM Test, Verification, and Certification**

- a) The Contractor shall execute the Spacecraft Master Verification Plan for the verification, qualification, certification, and acceptance of the Service Module, subsystems, and components.
- b) The Contractor shall perform qualification tests using **DRD CEV-T-037**, *Qualification Test Procedures*, and document the test results in **DRD CEV-T-038**, *Qualification Test Report* and

Crew Exploration Vehicle – (CEV)

Modification 994

DRD CEV-T-017, Certification Data Package. The Contractor shall perform qualification testing at component, SM and intermediate levels of assembly as necessary to accumulate the data necessary for Service Module certification. The Contractor shall produce a Certification Data Package for each component and each subsystem in the Service Module, and the Service Module. . The contractor shall develop a dedicated qualification Service Module for system-level qualification testing. Following the completion of system-level qualification testing, the contractor shall maintain configuration control of the dedicated qualification SM and store it in an environmentally-controlled and access-controlled area.

- c) The Contractor shall perform acceptance testing at the Service Module and Spacecraft Adapter and SM component level using **DRD CEV-T-039, Acceptance Test Procedures**, and document the results using **DRD CEV-T-040, Acceptance Data Package**. An Acceptance Data Package shall be produced for Service Modules for Orion 1 and 2.
- d) The Contractor shall hold Test Readiness Reviews (TRRs) before all formal verification activities. The Contractor shall make subsystem and module test procedures available to NASA. The Contractor shall invite NASA to witness all formal verification activities, including TRRs and test executions.
- e) The Contractor shall conduct verification testing of all interface designs and requirements within the Service Module (between subsystems, and between components).
- f) If the Contractor utilizes modeling and simulation to conduct analysis in support of verification specification compliance, the Contractor shall comply with **DRD CEV-T-001, Integrated Models, Simulations and Support Plan**, and **DRD CEV-T-002, CEV Engineering Models**.
- g) The Contractor shall provide the integration, test, & verification facilities required to test and certify the Service Module and all SM subsystems and components. The Contractor shall invite NASA to witness all subsystem facility design reviews and certification activities.
- h) The Contractor shall provide the Integration, Test, & Verification (IT&V) facilities required to complete integrated verification of the Service Module. The requirements for the IT&V facilities shall be derived from the products developed under Section 10.1, Test, Verification Management and Administration.
- i) The Contractor shall develop, implement, and maintain an SM Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of Service Module system.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 10.2

- DRD-CEV-T-015: Service Module Volume Master Verification Plan

The Contractor shall deliver the following DRDs for the Qualification Vehicle SM, incorporating all lower level element Qualification data. These DRDs will be also collected into the DRD specified in Sections 10.2 and 10.3 for the integrated CEV.

- DRD CEV-T-017 Certification Data Package
- DRD CEV-T-037: Qualification Test Procedures
- DRD CEV-T-038: Qualification Test Report

The Contractor shall deliver the following DRDs for the Production Vehicle SM, incorporating all lower level element acceptance data. These DRDs will be also collected into the DRD specified in Sections 10.2 and 10.3 for the integrated CEV.

- DRD CEV-T-039: Acceptance Test Procedures
- DRD CEV-T-040: Acceptance Data Package

6.2.6 SM Assembly, Integration, and Production

- a) The Contractor shall integrate, assemble, certify, acceptance test, and deliver flight Service Module meeting the requirements for configurations below.
- b) The Contractor shall develop and implement an imagery plan to provide imagery (e. g., still photo, motion picture, digital imagery, or video) of the Service Module, subsystems, and components during manufacturing, assembly, test, integration, and close-out to document the hardware configuration. The Contractor shall include the plan and imagery in **DRD CEV-T-088**, *CEV Imagery Plan/Imagery Deliverables*.
- c) The Contractor shall develop and implement plans detailing the design and construction of all Service Module transportation support equipment, and the plans for transportation of the Service Module and Spacecraft Adapter to the processing and/or launch sites. These plans shall be included in **DRD CEV-T-087**, *CEV Spacecraft Handling and Transportation Plan*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 2.7.2:

- DRD CEV-T-087: CEV Handling and Transportation Plan

The following module specific information is collected in the DRDs specified in Section 2.10

- DRD CEV-T-086: Manufacturing and Assembly Plan
- DRD CEV-T-088: CEV Imagery Plan/Imagery Deliverables

6.2.6.1 SM Flight Hardware AIP

- a) The Contractor shall integrate, assemble, certify, acceptance test, and deliver flight Service Module meeting the requirements for the configurations below.
- b) The Contractor shall develop and implement plans detailing the design and construction of all Service Module transportation support equipment, and the plans for transportation of the Service Module to the processing and/or launch sites. These plans shall be included in **DRD CEV-T-087**, *CEV Spacecraft Handling and Transportation Plan*.
- c) The Contractor shall deliver 1 production SM (including the SA) for Orion 1 and 1 production SM for Orion 2 (including the SA).
- d) The Contractor shall design, develop, produce, integrate, verify, validate, certify, document, and deliver Service Module GSE in accordance with all requirements in CXP-72000 04002, Systems Requirements for the Crew Exploration Vehicle Element (CEV SRD), and in this SOW, and in accordance with **DRD CEV-O-008**, *Ground Systems Requirements, Plans, Reports, and Design Data, Volume II, Ground Systems End Item Implementation Plan and Report*. The Contractor shall plan for and deliver the GSE end items in accordance with Attachment J-9. The Contractor shall use the following applicable documents for design and development of Contractor-provided GSE:
 - NASA-STD-5005B: NASA Standard for Ground Support Equipment (and associated Applicable Document Children as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List).
- e) The Contractor shall develop and update **DRD CEV-O-008**, *Ground Systems Requirements, Plans, Reports, and Design Data, Volume III, Systems Operations and Maintenance Plan and Requirements Documentation*, for the ground support equipment provided for the Service Module.

Crew Exploration Vehicle – (CEV)

Modification 994

- f) The Contractor shall develop, maintain and deliver all technical models and drawings of the GSE associated with the Service Module in accordance with **DRD CEV-T-003**, *CEV CAD Models*, and **DRD CEV-T-004**, *CEV Drawings*.
- g) The Contractor shall develop and update 2-D and 3-D simulation models of the Contractor-provided Service Module and Contractor-provided Service Module GSE to assess clearances, placement, conflicts and the moving of hardware in accordance with **DRD CEV-T-003**, *CEV CAD Models*. The Contractor shall develop and deliver these models in accordance with SOW Section 2.4.
- h) The Contractor shall develop and deliver **DRD CEV-T-040**, *Acceptance Data Package*, for each Contractor-provided Service Module GSE end item.
- i) The Contractor shall provide initial spares, concurrent with the delivery of the GSE end items and in accordance with the provisioning procedures in **DRD CEV-T-011**, *Integrated Logistics Support Plan*, and **DRD CEV-T-012**, *Logistics Support Analysis*, for all Contractor-provided Service Module GSE. (IDIQ)
- j) The Contractor shall complete the DD-250 for the Contractor-provided Service Module GSE and deliver the Contractor-provided Service Module GSE to the NASA-designated facilities.
- K) For Orion 1, the government shall provide a Developmental Flight Instrumentation system (DFI) and installation engineering to be installed by the Contractor. (IDIQ)

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following SM & SA GSE data is incorporated in the DRD specified in Section 2.4:

- DRD CEV-T-003: CEV CAD Models
- DRD CEV-T-004: CEV Drawings

The following SM & SA GSE data is incorporated in the DRD specified in Section 2.7.2:

- DRD CEV-O-008: Ground Systems Requirements, Plans, Reports, and Design Data
- DRD CEV-T-040: Acceptance Data Package
- DRD CEV-T-087: CEV Handling and Transportation Plan

6.2.6.2 SM Test Article Design and Production

For PA1, AA1, PA2, and AA2, the government will provide the Separation Ring (SR) that performs the CM/SM Retention and Release (R&R) function and is the interface to the Abort Test Booster. The following requirements only apply to contractor provided SR components, SMs and SAs.

- a) For AA1, PA2, and AA2, the Contractor shall design, develop, and procure, build, verify, and deliver three (3) sets of CM/SM R&R mechanisms kits in accordance with the requirements and specifications developed in section 10.6.4, Flight Test Article (FTA) DDT&E, documented in **DRD CEV-D-004**, *Flight Test Article (FTA) Design and Data Book*.
- b) For AA1, PA2 and AA2 the Contractor shall deliver three (3) CM/SM Umbilical Mechanism Kits, as defined in Attachment J-9.
- c) For AA1, PA2, and AA2, the Contractor shall validate and verify the mechanisms kit design as specified in **DRD- CEV- T-015**, *Volume VII, Master Verification Plan, Flight Test Volume and documented in accordance with section 10.6.4, FTA DDT&E*, paragraph y.
- d) For AA1 the Contractor shall design, develop, procure, and build a harness kit between the T0 interface, CM/SR interface, and Contractor-provided mechanisms kit with the

Crew Exploration Vehicle – (CEV)

Modification 994

requirements and specifications developed in section 10.6.4 FTA DDT&E; documented in **DRD CEV-D-004, Test Article (FTA) Design and Data Book.**

- e) For PA2 and AA2, the Contractor shall design, develop, procure, and build a harness kits between the T-0 interface, and Contractor-provided mechanisms kit with the requirements and specifications developed in section 10.6.4 FTA DDT&E; documented in **DRD CEV-D-004, Test Article (FTA) Design and Data Book.**
- f) For Ares-1-Y, the contractor shall deliver one (1) production representative SM with mass simulators and ballast which supports meeting flight test objectives defined in CxP-72166. This SM and SA is unique in that it will be configured with the minimum functionality required to execute a LAS abort within 30 seconds of 1st to 2nd stage staging. The SM and SA are configured to achieve flight representative OML/geometry, mass, and dynamic characteristics.
- g) Reserved
- h) Reserved
- i) The Contractor shall design, develop, produce, integrate, verify, validate, certify, document, and deliver SM FTA Unique GSE in accordance with all requirements in CxP 72000, Systems Requirements for the Crew Exploration Vehicle Element (CEV SRD), and in this SOW, and in accordance with **DRD CEV-O-008, Ground Systems Requirements, Plans, Reports, and Design Data, Volume II, Ground Systems End Item Implementation Plan and Report.** The Contractor shall use the following applicable documents for design and development of Contractor-provided GSE:
 - o NASA-STD-5005B: NASA Standard for Ground Support Equipment (and associated Applicable Document Children as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List).
- j) The Contractor shall deliver a SM test article for a Ground Vibration Test at MSFC in accordance with CxP 72234, Integrated Vehicle Ground Vibration Test Task Plan. This SM test article can either be simulated modules or residual test articles refurbished to support specific requirements of the test. Support for Integrated Vehicle Ground Vibration Test shall be in accordance with the Ares IVGVT & Orion Bilateral Exchange Agreement (BEA).
- k) The Contractor shall support and provide SM and SA ground test articles for a Ground Vibration Test at MSFC in accordance with CxP 72234, Integrated Vehicle Ground Vibration Test Task Plan. l) The Contractor shall develop **DRD-CEV-D-002, Flight Test Article Requirements** for Pad Abort and Ascent Abort tests.
- m) The Contractor shall develop and maintain **DRD CEV-D-005, Flight Test Article (FTA) Validation and Verification Data Book**, identified in Section 10.6, for the SM FTA.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD-CEV-T-015: FTA Volume Master Verification Plan (per Section 10.6)

The following Module specific information is collected in the DRDs specified in Section 10.6.4:

- DRD-CEV-D-002, Flight Test Article <level> Requirements
- DRD CEV-D-004: Flight Test Article (FTA) Engineering Design and Data Book
- DRD CEV-D-005: Flight Test Article (FTA) Validation and Verification Data Book
- DRD CEV-T-031: CEV <Level> Requirements Specification, for the Flight Test Article.

The following Module specific information is collected in the DRDs specified in Section 2.7

- DRD CEV-O-008: Ground Systems Requirements, Plans, Reports, and Design Data, Volume II, Ground Systems End Item Implementation Plan and Report.

6.3 Reserved

6.4 Launch Abort System

Launch Abort System includes the tasks required for the design, development, production, assembly, test, and certification of the Launch Abort System (LAS) and efforts to deliver the completed LAS for Spacecraft integration. Development of unique launch abort system components and integration of all other subsystem components that make up the abort system is the responsibility of the launch abort system team.

6.4.1 LAS Management and Administration

LAS Management and Administration includes the efforts for planning, organizing, directing, coordinating, controlling, and approval processes used to accomplish Launch Abort System Development objectives.

- a) NASA will maintain detailed oversight of all Launch Abort System design activities. The Contractor shall maintain responsibility for delivery of a design that meets the requirements. The detailed process discussion to accomplish this can be found in CxP-72008, CEV Project Plan. The Contractor shall include NASA personnel on all design teams established by the Contractor.

6.4.2 LAS System Engineering and Integration

LAS Systems Engineering and Integration consists of the efforts to lead the Launch Abort System overall system architecture definition and engineering functions. This includes the technical and management efforts of directing and controlling the integrated engineering effort for the LAS. This also includes the effort to coordinate LAS integration with the CEV integration functions described in Section 2.

- a) The Contractor shall define the modules, subsystems, components, and software units that make up the Launch Abort System per the requirements and deliverables included in this section.
- b) The Contractor shall develop, maintain, and deliver all drawings and technical Computer Aided Design (CAD) models of the Launch Abort System, subsystems and components. The Contractor shall use **DRD CEV-T-003**, *CEV CAD Models*, and **DRD CEV-T-004**, *CEV Drawings*, as the template for development and delivery of these items.
- c) The Contractor shall develop and maintain models and simulations for the Launch Abort System, subsystems, and components using **DRD CEV-T-002**, *CEV Engineering Models*.
- d) The Contractor shall document and maintain ICD(s) for the government furnished products below:
 - o Pyrotechnics initiators
- e) Reserved
- f) The Contractor shall document Launch Abort System subsystem-level requirements using **DRD CEV-T-031**, *CEV <Subsystem> Requirements Specifications*.
- g) The Contractor shall document component-level requirements within the Launch Abort System using **DRD CEV-T-031**, *CEV <Component> Requirements Specifications*.
- h) The Contractor shall develop and use integrated models with sufficient fidelity to allow accurate trades to be performed for the design and development of the launch abort system to meet the requirements specified by the CEV Project.

Crew Exploration Vehicle – (CEV)

Modification 904

- i) The Contractor shall document all hardware interfaces requirements using **DRD CEV-T-035, Internal Interface Requirement Document (IRD)**. The Contractor shall produce an IRD for each module that interfaces with another module. The Contractor shall produce an IRD for each subsystem that interfaces with another subsystem.
- j) The contractor shall develop **DRD CEV-T-081 Launch Abort System Design and Data Book** which contains detailed design descriptions for the LAS module, subsystems and major components, subsystem definitions, requirements analyses, operational analyses, as well as maintainability and testing data.
- k) The Contractor shall develop and maintain the Launch Abort System portion of the CEV Specification and Drawing Trees, **DRD-CEV-T-032**. The top drawing shall be incorporated into the CEV System Drawing Tree identified in Section 2.2

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-031: Launch Abort System <Subsystem> Requirements Specification
- DRD-CEV-T-031: LAS <Component> Requirements Specifications
- DRD CEV-T-032: CEV Specification and Drawing Tree for the Service Module and Spacecraft Adapter
- DRD CEV-T-035: LAS Subsystem Internal Interface Documents
- DRD CEV-T-081: LAS Design and Data Book

The following Module specific information is collected in the DRDs specified in Section 2.4.3

- DRD CEV-T-002: LAS Engineering Models
- DRD-CEV-T-032 LAS Specification and Drawing Trees
- The following deliverables are are separate Module deliverables and are integrated by reference into the System level submittal in 2.3.
- DRD CEV-T-003:LAS CAD Models
- DRD CEV-T-004: LAS Drawings

6.4.3 LAS Subsystems

This Section includes the work required to design, develop, produce, and test through certification and acceptance all Launch Abort System subsystems required to meet CEV module-level and interface requirements.

- a) The Contractor shall design, develop, test, certify, and deliver Launch Abort System subsystem hardware complying with all requirements in CXP-72000, Systems Requirements for the Crew Exploration Vehicle Element (CEV SRD) (including the listed applicable documents and those included in this Statement of Work (SOW) See Section 2.2).
- b) In support of the Launch Abort System avionics development effort, the Contractor shall provide the following for each subsystem:
 - Validation of the subsystem's software requirements
 - Validation of subsystem models/simulations used for flight software and integrated avionics verification
- c) The Contractor shall provide system and LAS-level design definition data in the **DRD CEV-T-033, Architectural Design Document** and design definition and data down to the component level in the Subsystem Design and Data Books.
- d) The Contractor shall hold subsystem design reviews prior to the LAS system PDR and CDR.

Crew Exploration Vehicle – (CEV)

Modification 904

- e) The Contractor shall test (acceptance test only) and deliver flight spares for the Launch Abort System subsystems. The Contractor shall provide a spare parts list as part of the **DRD CEV-T-012, Logistics Support Analysis (Recommended Spare Parts List)**. (IDIQ)
- f) The Contractor shall deliver one ship set of Launch Abort System flight spares (i.e., 1 copy of every line replaceable unit) (IDIQ)
- g) The Contractor shall deliver 2 production LAS for Orion 1 and Orion 2.
- h) The Contractor shall use the following standards and requirements documents for developing all LAS subsystems:
 - o JPR 8080.5, JSC Design and Procedural Standards (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List) (exclusive of government "shalls")
 - o CXP-70024, Constellation Human Systems Integration Requirements (HSIR) (and associated Children documents as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List)
- i) The Contractor shall use the following standards for developing all LAS subsystems:
 - o AIAA-S-080, AIAA Standard for Space Systems – Metallic Pressure Vessels Pressurized Structures, and Pressure Components
 - o ANSI/AIAA-S-081A-2006, AIAA Standard for Space Systems – Composite Overwrapped Pressure Vessels

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 2.7.2

- DRD CEV-T-012: Logistics Support Analysis

The following module specific information is collected in the DRDs specified in Section 2.2

- DRD CEV-T-033: Architecture Design Document

6.4.3.1 Reserved**6.4.3.2 LAS Command & Data Handling (C&DH)**

- a) The Contractor shall document the design for all Launch Abort System C&DH hardware as specified in **DRD CEV-T-047, Avionics Design and Data Book Volume II - C&DH/Instrumentation Subsystem Data**.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 2.6.1

- DRD CEV-T-047: Avionics Design and Data Book, Volume II – C&DH/Instrumentation Subsystem Data

6.4.3.3 LAS Communications and Tracking (C&T)

- a) For the LAS, the Contractor shall prepare, deliver, and maintain DRD CEV-T-047, Avionics Design and Data Book Volume III - Communications and Tracking Subsystem Data.

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.1

- DRD CEV-T-047: Avionics Design and Data Book, Volume III – Communications and Tracking Subsystem Data Book

6.4.3.4 *Reserved***6.4.3.5 *LAS Electrical Power System***

- a) The Contractor shall document the design for all Launch Abort System EPS Hardware as specified in **DRD CEV-T-059**, *Electrical Power System (EPS) Design and Data Book*
- b) The Contractor shall participate with the Constellation Program in the development of DRD CEV-T-060, *Electrical Power Quality Specification Requirements Document*.

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.5

- DRD CEV-T-059: LAS Electrical Power System (EPS) Design and Data Book
- DRD CEV-T-060: LAS Electrical Power Quality Specification Requirements Document

6.4.3.6 *LAS Mechanisms*

- a) The Contractor shall document the design for all Launch Abort System mechanisms as specified in DRD CEV-T-061, *Mechanical Systems Design and Data Book*, and **DRD CEV-T-062**, *Stress Analysis Report*.

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.6

- DRD CEV-T-061: LAS Mechanical Systems Design and Data Book
- DRD CEV-T-062: LAS Stress Analysis Report

6.4.3.7 *LAS Passive Thermal Control*

- a) The Contractor shall develop thermal analytical models to support Launch Abort System thermal analyses.
- b) The Contractor shall document the design for all Launch Abort System Passive Thermal Control as specified in **DRD CEV-T-063**, *PTC Systems Design and Data Book*, and **DRD-CEV-T-064**, *Passive thermal Control Mathematical Models and Documentation*

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.7

- DRD CEV-T-063: LAS Passive Thermal Control Design and Data Book (PTCDDB)
- DRD CEV-T-064: LAS Passive Thermal Control Mathematical Models and Documentation

6.4.3.8 *Reserved*

6.4.3.9 *LAS Structures*

- a) The Contractor shall perform structural analysis on all Launch Abort System structures, including pressure vessels, to show that all elements of the design such as the strength, stiffness, structural stability, and life meet all specified criteria for the anticipated loads and environments.
- b) The Contractor shall perform Launch Abort System loads and dynamics analyses and document the results in **DRD CEV-T-067**, *Structural Loads Data Book*.
- c) The Contractor shall perform Launch Abort System stress and fatigue analyses and document the results in **DRD CEV-T-062**, *Stress Analysis Report*.
- d) The Contractor shall develop Launch Abort System models to support integrated Constellation vehicle analyses as well as CEV loads and stress analyses. The Contractor shall deliver **DRD CEV-T-068**, *Structures Mathematical Models and Documentation*, which will deliver and describe the mathematical models used in the Launch Abort System system, subsystem, and component loads and stress analyses.
- e) The Contractor shall implement a fracture control program and identify fracture critical parts to protect against catastrophic structural hazards associated with flaw presence, fatigue crack propagation and fracture. The Contractor shall deliver and implement **DRD CEV-T-069**, *Fracture Control Plan*, and **DRD CEV-T-070**, *Fracture Control Summary Report*.
- f) The Contractor shall use NASA-HDBK-7005, Dynamic Environmental Criteria, as a guidance document to support the **DRD CEV-T-015**, *Master Verification Plan* DRD product development activity.
- g) The Contractor shall use the following standards for designing and analyzing the Launch Abort System structures subsystem:
 - o The Contractor shall use the applicable requirements in Contract Attachment J-3, Table 1.2, Applicable Environmental Data Documents Requirements Data Book
 - o JSC-62550, Structural Design and Verification Criteria for Glass, Ceramics and Windows in Human Space Flight Applications
 - o NASA-STD-5001, Structural Design and Test Factors of Safety for Space Flight Hardware
 - o NASA-STD-5002, Loads Analyses of Spacecraft and Payloads
 - o NASA STD-(I)-5019, 9-12-2006, Fracture Control Requirements for Space Flight Hardware (children documents are to be used by the contractor as a level of standards that must be met or exceeded if alternative standards are recommended by the contractor)
- h) The contractor shall produce an engineering development Launch Abort System structure for use in environmental testing (Ground Test Article). (See Section 2.6.9 h)
- i) The Contractor shall deliver an LAS Structural Test Article (used for structural verification static and dynamic testing) via the DD149 process.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 2.6.9

- DRD CEV-T-062: LAS Stress Analysis Report
- DRD CEV-T-067: LAS Structural Loads Data Book

Crew Exploration Vehicle – (CEV)

Modification 994

- DRD CEV-T-068: LAS Structures Mathematical Models and Documentation
- DRD CEV-T-070: LAS Fracture Control Summary Report
- DRD CEV-T-015 Structures Subsystem Volume Master Verification Plan

6.4.3.10 LAS Propulsion

- a) The Contractor shall perform design, development, test, certification and delivery of all Launch Abort System propulsion systems and develop all propulsion related DRD products.
- b) The Contractor shall develop, document, implement, and execute comprehensive verification activities and associated processes for all Launch Abort System propulsion systems in order to certify the propulsion systems for compliance with CEV component, subsystem, module, Spacecraft system, and vehicle-level requirements. The Contractor shall also design, fabricate and test integrated Launch Abort System propulsion systems in order to evaluate and certify integrated propulsion system hot fire performance for each propulsion application. The Contractor shall also design, fabricate, and test integrated Launch Abort System propulsion systems to evaluate and certify integrated propellant system storage and conditioning designs and capabilities in order to evaluate and certify propellant conditioning performances. (See Section 2.6.10)
- c) The Contractor shall document the design for all LAS propulsion as specified in **DRD CEV-T-071, Propulsion Systems Design and Data Book**.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 2.6.10

- DRD CEV-T-071: LAS Propulsion Systems Design and Data Book

6.4.3.11 Reserved

6.4.3.12 Reserved

6.4.3.13 Pyrotechnics

- a) The Contractor shall perform device level preliminary design reviews and critical design reviews for each Launch Abort System pyrotechnic device not provided by NASA. The Contractor shall conduct development, qualification, and acceptance testing on all other pyrotechnic devices selected for the Launch Abort System. The Contractor shall conduct Phase I, Phase II, and Phase III technical reviews on all other pyrotechnic devices selected for the Launch Abort System per the requirements of JSC 62809, Rev. C Constellation Spacecraft Pyrotechnic Specification and JPR 8080.5 Standards P1-P7.
- b) Launch Abort System specific stress analysis reports will be collected in the DRD (**DRD CEV-T-062, Stress Analysis Report**) specified in Section 2.6.13 for all pyrotechnic devices selected for the Launch Abort System.
- c) The Contractor shall document the design for the Launch Abort System Module pyrotechnic subsystem as specified in **DRD CEV-T-075, Pyrotechnic Subsystem Design and Data Book**.

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.13

- DRD CEV-T-062: Stress Analysis Report
- DRD CEV-T-075: Pyrotechnic Subsystem Design and Data Book

6.4.3.14 Reserved**6.4.3.15 LAS Guidance, Navigation, and Control (GN&C)**

- a) The Launch Abort System GN&C requirements design and functional verification effort will be performed through the use of specialized mode teams. NASA will co-lead with the Contractor in the development of detailed design requirements for the Launch Abort System GN&C flight system. The Contractor shall document the Launch Abort System GN&C requirements in **DRD CEV-T-031**, *CEV GN&C Subsystem Requirements Specification*, and **DRD CEV-T-048**, *Software Requirements Specification*. The Contractor shall provide support to the following teams:
 - CEV Ascent/Abort Mode Team
 - Flight Mechanics/Mission Design Mode Team
- b) The Contractor shall document the design for the LAS propulsion subsystem as specified in **DRD CEV-T-078**, *GN&C Systems Design and Data Book*.

Deliverables

The following module specific information is collected in the DRDs specified in Section 6.1.2

- DRD CEV-T-031: LAS GN&C <Subsystem > Requirements Specification
- DRD CEV-T-031 LAS GN&C <Components> Requirements Specification

The following module specific information is collected in the DRDs specified in Section 6.5.2

- DRD CEV-T-048 Software Requirements Specification

The following module specific information is collected in the DRDs specified in Section 2.6.15

- DRD CEV-T-078: LAS GN&C Design and Data Book

6.4.3.16 LAS Wiring

- a) The Contractor shall develop a wiring database that provides definition down to the level of pin-to-pin connectivity for all electrical harnesses and optical cables used on the Launch Abort System for ground, launch, flight, and recovery operations including testing, verification, calibration, and maintenance. The Contractor shall deliver the wiring database to NASA as **DRD CEV-T-080**, *CEV Wiring Database and Reports*. The Contractor shall provide a hierarchical path/signal structure which links the wiring database to **DRD CEV-T-046**, *CEV Data and Command Dictionary*.
- b) The Contractor shall develop, manufacture/fabricate, test, install, and certify all Launch Abort System wiring in accordance with DRD CEV-T-079, and **DRD CEV-T-080**, *CEV Wiring Database and Reports*.

Deliverables

The following module specific information is collected in the DRDs specified in Section 2.6.1

Crew Exploration Vehicle – (CEV)

Modification 994

- DRD CEV-T-046: CEV Data and Command Dictionary

The following module specific information is collected in the DRDs specified in Section 2.6.16

- DRD CEV-T-079: LAS Wiring Plan
- DRD CEV-T-080: LAS Wiring Database and Reports

6.4.4 Reserved

6.4.5 LAS Test, Verification, and Certification

- a) The Contractor shall execute the Spacecraft Master Verification Plan for the verification, qualification, certification, and acceptance of the Launch Abort System, subsystems, and components.
- b) The Contractor shall perform qualification tests using **DRD CEV-T-037, Qualification Test Procedures**, and document the test results in **DRD CEV-T-038, Qualification Test Report**, and **DRD CEV-T-017, Certification Data Package**. The Contractor shall perform qualification testing at component, LAS and intermediate levels of assembly as necessary to accumulate the data necessary for Launch Abort System certification. The Contractor shall produce a Certification Data Package for each component and each subsystem in the Launch Abort System, the Launch Abort System, and spacecraft Note: Software test documentation is handled in SOW section 6.2.1.1, Flight Software. The contractor shall develop a dedicated qualification inert Launch Abort System for system-level qualification testing. Following the completion of system-level qualification testing, the contractor shall maintain configuration control of the dedicated qualification LAS and store it in an environmentally-controlled and access-controlled area.
- c) The Contractor shall perform acceptance testing at the Launch Abort System and LAS component level using **DRD CEV-T-039, Acceptance Test Procedures**, and document the results using **DRD CEV-T-040, Acceptance Data Package**. An Acceptance Data Package shall be produced for Launch Abort Systems for Orion 1 and 2.
- d) The Contractor shall hold Test Readiness Reviews (TRRs) before all formal verification activities. The Contractor shall make subsystem and module test procedures available to NASA two weeks prior to each TRR. The Contractor shall invite NASA to witness all formal verification activities, including TRRs and test executions.
- e) The Contractor shall conduct verification testing of all interface designs and requirements within the Launch Abort System (between modules, between subsystems, and between components).
- f) If the Contractor utilizes modeling and simulation to conduct analysis in support of verification specification compliance, the Contractor shall comply with **DRD CEV-T-001, Integrated Models, Simulations and Support Plan**, and **DRD CEV-T-002, CEV Engineering Models**.
- g) The Contractor shall provide the integration, test, & verification facilities required to test and certify the Launch Abort System and all LAS subsystems and components. The Contractor shall invite NASA to witness all subsystem facility design reviews, test, verification, and certification activities.
- h) The Contractor shall provide the Integration, Test, & Verification (IT&V) facilities required to complete integrated verification of the Launch Abort System. The requirements for the IT&V facilities shall be derived from the products developed under Section 10.1, Spacecraft Test, Verification and Certification. LAS Master Verification Plan, per **DRD CEV-T-015**, that details the Contractor's plan for verifying, certifying, and acceptance of Launch Abort System.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 10.2

- DRD-CEV-T-015: LAS Volume Master Verification Plan

The Contractor shall deliver the following DRDs for the Qualification Vehicle LAS, incorporating all lower level element Qualification data. These DRDs will be also collected into the DRD specified in Sections 10.2 and 10.3 for the integrated CEV.

- DRD CEV-T-017 Certification Data Package
- DRD CEV-T-037: Qualification Test Procedures
- DRD CEV-T-038: Qualification Test Report

The Contractor shall deliver the following DRDs for the Production Vehicle LAS, incorporating all lower level element acceptance data. These DRDs will be also collected into the DRD specified in Sections 10.2 and 10.3 for the integrated CEV.

- DRD CEV-T-039: Acceptance Test Procedures
- DRD CEV-T-040: Acceptance Data Package

6.4.6 LAS Assembly, Integration, and Production (AIP)

- The Contractor shall integrate, assemble, certify, acceptance test, and deliver flight Launch Abort System meeting the requirements configurations below.
- The Contractor shall develop and implement an imagery plan to provide imagery (e. g., still photo, motion picture, digital imagery, or video) of the Launch Abort System, and components during manufacturing, assembly, test, integration, and close-out to document the hardware configuration. The Contractor shall include the plan and imagery in **DRD CEV-T-088, CEV Imagery Plan/Imagery Deliverables**.
- Reserved
- The Contractor shall provide the launch abort system for the CEV launch abort flight tests and flight vehicles.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following module specific information is collected in the DRDs specified in Section 2.7.2:

- DRD CEV-T-087: CEV Handling and Transportation Plan

The following module specific information is collected in the DRDs specified in Section 2.10

- DRD CEV-T-086: Manufacturing and Assembly Plan
- DRD CEV-T-088: CEV Imagery Plan/Imagery Deliverables

6.4.6.1 LAS Flight Hardware AI&P

- The Contractor shall integrate, assemble, certify, acceptance test, and deliver flight Launch Abort Systems meeting the requirements for the configurations below.
- The Contractor shall develop and implement plans detailing the design and construction of all Launch Abort System transportation support equipment, and the plans for transportation of the Launch Abort System to the processing and/or launch sites. These plans shall be included in **DRD CEV-T-087, CEV Spacecraft Handling and Transportation Plan**.
- The Contractor shall deliver a production LAS for Orion 1 and a production LAS for Orion 2.

Crew Exploration Vehicle – (CEV)

Modification 994

- d) The Contractor shall design, develop, produce, integrate, verify, validate, certify, document, and deliver Launch Abort System GSE in accordance with all requirements in CXP-72000, Systems Requirements for the Crew Exploration Vehicle Element (CEV SRD), and in this SOW, and in accordance with **DRD CEV-O-008**, *Ground Systems Requirements, Plans, Reports, and Design Data, Volume II, Ground Systems End Item Implementation Plan and Report*. The Contractor shall plan for and deliver the GSE end items in accordance with Attachment J-9.—The Contractor shall use the following applicable documents for design and development of Contractor-provided GSE:
- o NASA-STD-5005B: NASA Standard for Ground Support Equipment (and associated Applicable Document Children as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List).
- e) The Contractor shall develop and update **DRD CEV-O-008**, *Ground Systems Requirements, Plans, Reports, and Design Data, Volume III, Systems Operations and Maintenance Plan and Requirements Documentation*, for the ground support equipment provided for the Launch Abort System.
- f) The Contractor shall develop, maintain and deliver all technical models and drawings of the GSE associated with the Launch Abort System in accordance with **DRD CEV-T-003**, *CEV CAD Models*, and **DRD CEV-T-004**, *CEV Drawings*.
- g) The Contractor shall develop and update 2-D and 3-D simulation models of the Contractor-provided Launch Abort System and Contractor-provided LAS GSE to assess clearances, placement, conflicts and the moving of hardware in accordance with **DRD CEV-T-003**, *CEV CAD Models*. The Contractor shall develop and deliver these models in accordance with SOW Section 2.4.
- h) The Contractor shall develop and deliver **DRD CEV-T-040**, *Acceptance Data Package*, for each Contractor-provided Launch Abort System GSE end item.
- i) The Contractor shall provide initial spares, concurrent with the delivery of the GSE end items and in accordance with the provisioning procedures in **DRD CEV-T-011**, *Integrated Logistics Support Plan*, and **DRD CEV-T-012**, *Logistics Support Analysis*, for all Contractor-provided Service Module GSE. (IDIQ)
- j) For Orion 1, the Contractor shall provide the installation design, associated hardware and installation of NASA provided LAS Development Flight Instrumentation (DFI) elements.
- j) The Contractor shall complete the DD-250 for the Contractor-provided Launch Abort System GSE and deliver the Contractor-provided LAS GSE in accordance with Attachment J-9. to the NASA-designated facilities.

Deliverables

The Contractor shall deliver and maintain the following document(s):

The following LAS GSE data is incorporated in the DRD specified in Section 2.4:

- DRD CEV-T-003: CEV CAD Models
- DRD CEV-T-004: CEV Drawings

The following LAS GSE data is incorporated in the DRD specified in Section 2.7.2:

- DRD CEV-O-008: Ground Systems Requirements, Plans, Reports, and Design Data
- DRD CEV-T-040: Acceptance Data Package
- DRD CEV-T-087: CEV Handling and Transportation Plan

6.4.6.2 LAS Test Article Design and Production

The Contractor shall provide all the LASs.

Crew Exploration Vehicle – (CEV)

Modification 994

- a) For PA1 and AA1, the Contractor shall design and develop the developmental LAS's using the system, module, sub-system, and component level requirements and specifications developed in Section 10.6.4, Flight Test Article (FTA) DDT&E ; documented in **DRD CEV-D-002, Flight Test Article <Level> Specification ..**
- b) For PA1 and AA1, the Contractor shall deliver two (2) prototype LAS.
- c) For PA2, and AA2, the Contractor shall design and develop the developmental LAS's using the system, module, sub-system, and component level requirements and specifications developed in Section 10.6.4, Flight Test Article (FTA) DDT&E ; documented in **DRD CEV-D-002, Flight Test Article <Level> Specification.**
- d) For PA2 and AA2, the Contractor shall deliver two (2) development LAS.
- e) For PA1, AA1, PA2 and AA2, and Ares 1Y the Contractor shall provide the installation design, associated hardware and installation of NASA provided LAS Development Flight Instrumentation (DFI) elements.
- f) For Ares-1Y the Contractor shall deliver a production LAS
- g) The Contractor shall design, develop, produce, integrate, verify, validate, certify, document, and deliver LAS FTA unique GSE in accordance with all requirements in CXP 72000 Systems Requirements for the Crew Exploration Vehicle Element (CEV SRD), and in this SOW, and in accordance with **DRD CEV-O-008, Ground Systems Requirements, Plans, Reports, and Design Data, Volume II, Ground Systems End Item Implementation Plan and Report.** The Contractor shall use the following applicable documents for design and development of Contractor-provided GSE:
 - o NASA-STD-5005B: NASA Standard for Ground Support Equipment (and associated Applicable Document Children as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List).
- h) The Contractor shall provide the LAS side of a LAS to CM mechanical interface simulator (MIS) to be used for LAS/CM Retention and Release (R&R) mechanism fit checks, and functional tests.
- i) The Contractor shall provide LAS propulsion data and an LAS OML in the post-jettison configuration for the test range flight safety office to determine the nominal LAS impact area.
- j) The Contractor shall perform/support a structural calibration test of the LAS/CM R&R structural interface.
- k) The Contractor shall deliver a LAS test article for a Ground Vibration Test at MSFC in accordance with CxP 72234, Integrated Vehicle Ground Vibration Test Task Plan. This LAS test article can either be simulated modules or residual test articles refurbished to support specific requirements of the test. Support for Integrated Vehicle Ground Vibration Test shall be in accordance with the Ares IVGVT & Orion Bilateral Exchange Agreement (BEA).
- l) The Contractor shall develop **DRD-CEV-T-031, CEV FTA Requirements Specification for Flight Tests Ares 1Y** as defined in Section 10.6.4.
- m) The Contractor shall design, develop, produce, integrate, verify, validate, document, and deliver LAS FTA Unique GSE in accordance with all requirements in CxP 72000, Systems Requirements for the Crew Exploration Vehicle Element (CEV SRD), and in this SOW, and in accordance with **DRD CEV-O-008, Ground Systems Requirements, Plans, Reports, and Design Data, Volume II, Ground Systems End Item Implementation Plan and Report.** The Contractor shall use the following applicable documents for design and development of Contractor-provided GSE:
 - o NASA-STD-5005B: NASA Standard for Ground Support Equipment (and associated Applicable Document Children as specified in Attachment J-3, Applicable, Guidance, and Informational Documents List).

Crew Exploration Vehicle – (CEV)

Modification 904

- n) The Contractor shall validate and verify the flight test unique design as specified in **DRD CEV-T-015**, *Volume VII, Master Verification Plan, Flight Test Volume*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD-CEV-T-015: FTA Volume Master Verification Plan (per Section 10.6)

The following Module specific information is collected in the DRDs specified in Section 10.6.4:

- DRD CEV-O-002: Flight Test Article <Level> Specification for Pad Abort and Ascent Abort FTAs
- DRD CEV-T-031: CEV <Level> Requirements Specification, for the Flight Test Article for Ares-1Y

The following Module specific information is collected in the DRDs specified in Section 2.7

- DRD CEV-O-008: Ground Systems Requirements, Plans, Reports, and Design Data, Volume II, Ground Systems End Item Implementation Plan and Report.

6.5 CEV Software

CEV Software includes the tasks required for the design, development, production, assembly, test, and certification efforts to deliver the completed software for Spacecraft integration. This element includes all aspects of software production from the early stages of system specification through maintenance of the system in the field.

6.5.1 CEV Software Management and Administration

- a) The Contractor shall design, develop, produce, integrate, verify, validate, certify, operate, maintain, document, and deliver CEV flight and accompanying ground and test/simulation software in accordance with all Block 1A and Block 1B requirements and in this SOW.

6.5.2 CEV Software System Engineering

- a) The Contractor shall define, design, develop, test, qualify, integrate, verify, validate, deliver, and maintain all CEV software. The plans for accomplishing this work shall be documented in **DRD CEV-T-005**, *Software Development Plan*.
- b) The Contractor shall justify the reuse of existing software, modification of existing software, and the development of new software in **DRD CEV-T-005**, *Software Development Plan*.
- c) The Contractor shall, under CEV Project direction, participate in coordinating with the NASA IV&V Facility in accordance with NASA-STD-8739.8, NASA Software Assurance (Chapter 6 and 7) to plan for the participation of the NASA IV&V Facility in the software development lifecycle activities.
- d) The Contractor and its subcontractors' organizations associated with CEV software development responsibilities shall be at Software Engineering Institute Software Capability Maturity Model Integration (CMMI) - SE/SW/PPD Maturity Level III (Staged Representation) or higher prior to the CEV Preliminary Design Review. This requirement does not apply to commercial-off-the-shelf software procured for the CEV Project.
- e) The Contractor shall develop, update, and maintain all software and software development tools under configuration management in accordance with the **DRD CEV-T-006**, *Software Configuration Management Plan*.

Crew Exploration Vehicle – (CEV)

Modification 904

- f) The Contractor shall develop and maintain electronic Software Development Folders for all flight, ground, and test software per **DRD CEV-T-007**, *Software Development Folder*.
- g) The Contractor shall develop and maintain the Display Software Requirements Specification, using CxP 72242, Display Format Standards, and the CEV Display Format Dictionary, as applicable documents. This requirement specification shall be developed in accordance with DRD CEV-T-048, Software Requirements Specification. The display format dictionary shall be documented as an Appendix to DRD CEV-T-048, Software Requirements Specification.
- h) The Contractor shall use the following standards for designing, developing, and testing all software:
 - o NPR 7150.2 NASA Software Engineering Requirements
 - o NASA-STD-8739.8, NASA Software Assurance Standard (chapters 6 and 7)
- i) The Contractor shall allocate CEV Spacecraft requirements (section 2.2, Requirements Definition and Management) to the Computer Software Configuration Item (CSCI) level for the design of flight software and flight test software and maintain the allocations/requirements over the life of the system as development transitions to production (Schedule B) and sustaining engineering (A future contract action). The Contractor shall produce a Software Requirements Specification (SRS) for each CSCI, using **DRD CEV-T-048**, *Software Requirements Specification*.
- j) The Contractor shall allocate the requirements of each CSCI to the Computer Software Components (CSCs) and Computer Software Units (CSUs) levels. This design breakdown shall be documented in the *Interface Control Documents* (**DRD CEV-T-029**) and *Software Design Description* (**DRD CEV-T-050**) documents.
- k) The Contractor shall plan, execute and document trade studies to identify criteria and provide resolution data for flight software issues related to the selection of software, software tools, and hardware/software architectures (e.g., operating system selections and bus architectures). The Contractor shall determine the ability of the CEV system to be upgradeable to the Block 2 configuration and perform trade studies to determine that memory, throughput, and processing margins are adequate to meet the Block 2 configuration requirements. Trade study reports shall be documented per the requirements captured in **DRD CEV-T-009**, *CEV Analysis Reports*.
- l) The Contractor shall perform configuration management of the flight and flight support software within their configuration management system and provide “mirror imaging” of all software development folders, source code, and documentation into ICE on a weekly basis.
- m) The Contractor shall develop a flight software mission reconfiguration process that details the Contractor’s plan for flight-to-flight reconfiguration of the flight software and ground facility software to meet mission-specific requirements. The Contractor’s process shall address the changing of software parameters to account for vehicle modifications, vehicle differences, or to specify values for mission-specific requirements. The Contractor shall document the reconfiguration process plans, requirements, and design in **DRD CEV-T-005**, *Software Development Plan*, **DRD CEV-T-048**, *Software Requirements Specification*, and **DRD CEV-T-050**, *Software Design Description*. The Contractor shall develop tools to support the reconfiguration process.
- n) The Contractor shall design, develop, produce, integrate, verify, validate, certify, operate, maintain, document, and deliver a space-time partitioned real time operating system as part of the contractor’s flight software implementation.
- o) The Contractor shall use a modular software architecture that evolves with the vehicle’s capabilities. The Contractor’s flight software architecture shall be designed to support system evolution through incremental enhancements introduced within each block cycle. Each incremental enhancement shall add supplemental functional capabilities including selectable autonomy, mission management, and systems management in a time frame compatible with the increasing maturity of requirements and mission needs.

Crew Exploration Vehicle – (CEV)

Modification 904

- p) The Contractor shall ensure that ground systems software complies with Software Engineering standards identified within this section. For ground operations, the Contractor shall develop and update the software and interface requirements specifications for Contractor-provided ground systems software in accordance with **DRD CEV-T-048**, *Software Requirements Specification*, and implement the design processes and plans documented in the **DRD CEV-T-005**, *Software Development Plan*.
- q) The Contractor shall allocate the requirements of each Computer Software Configuration Item (CSCI) to the Computer Software Components (CSCs) and Computer Software Units (CSUs) levels for Contractor-provided GSE. The Contractor shall document the software design breakdown in accordance with the **DRD CEV-T-029**, *Interface Control Documents*, and **DRD CEV-T-050**, *Software Design Description*.
- r) For FTA efforts, the Contractor shall develop and update the software and interface requirements specifications for Contractor-provided flight support software in accordance with **DRD CEV-D-002**, *Flight Test Article (FTA) Specifications*.
- s) For FTA Efforts, the Contractor shall allocate the requirements of each Computer Software Configuration Item (CSCI) to the Computer Software Components (CSCs) and Computer Software Units (CSUs) levels for FTA software. The Contractor shall document the software design breakdown in accordance with the **DRD CEV-D-004**, *Flight Test Article (FTA) Engineering Design Data Book* defined in Section 10.6.4, *FTA DDT&E*.
- t) The contractor shall perform software build planning for each identified build and shall document the build planning results in accordance with **CEV-T-005**, *Software Development Plan, Volume 6 Software Build Plan*
- u) The Contractor shall develop, maintain, and deliver DRD CEV-T-049, *Monthly Software Metrics Report*.
- v) The Contractor shall develop, maintain, and deliver DRD CEV-T-056, *Software User Manual*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-005 : Software Development Plan
- DRD CEV-T-006: Software Configuration Management Plan
- DRD CEV-T-007: Software Development Folder
- DRD CEV-T-029: Interface Control Documents
- DRD CEV-T-048: Software Requirements Specifications
- DRD CEV-T-049: Monthly Software Metrics Report
- DRD CEV-T-050: Software Design Description
- DRD CEV-T-056: Software User Manual

The following software specific information is collected in the DRDs specified in Section 10.6.4:

- DRD CEV-D-002: Flight Test Article (FTA) Specifications
- DRD CEV-D-004: Flight Test Article (FTA) Engineering Design Data Book

6.5.3 CEV Software Production

- a) The Contractor shall develop all flight and ground support equipment software following the plans, processes, and standards outlined in **DRD CEV-T-005**, *Software Development Plan*, and section 6.5.2, *Software System Engineering*.
- b) The Contractor shall develop and deliver the FTA software and accompanying test software (source code, executables, build procedures, and graphical models/block diagrams from

Crew Exploration Vehicle – (CEV)

Modification 994

Computer Aided Software Engineering Tools) per NPR 7150.2, NASA Software Engineering Requirements using class C and class D definitions and requirements for this software.

- c) The Contractor shall maintain the FTA software and accompanying test software until the completion of testing as determined by the flight test matrix.
- d) The Contractor shall deliver Flight software (source code, executables, graphical models, block diagrams from Computer-Aided Software Engineering tools, and build procedures). Flight software deliveries shall start occurring at CDR and occur at a frequency of no more than every six months thereafter.
- e) The Contractor shall develop, maintain and deliver **DRD CEV-T-007**, *Software Development Folder*; **DRD CEV-T-050**, *Software Design Description*; **DRD CEV-T-051**, *Software Inspection and Peer Review Report*; **DRD CEV-T-055**, *Software Maintenance Plan*, and **DRD CEV-T-057**, *Version Description Document* in support of the CEV Software production and delivery.
- f) In support of the Flight Test Program, the Contractor shall maintain **DRD CEV-D-004**, *FTA Engineering Design and Data Book* for Flight Test Article related software.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-007: Software Development Folder
- DRD CEV-T-050: Software Design Description
- DRD CEV-T-051: Software Inspection and Peer Review Report
- DRD CEV-T-055: Software Maintenance Plan
- DRD CEV-T-056: Software User Manual
- DRD CEV-T-057: Version Description Document

The following software specific information is collected in the DRDs specified in Section 10.6.4:

- DRD CEV-D-004: Flight Test Article (FTA) Engineering Design Data Book

6.5.4 CEV Software T&V

- a) The Contractor shall perform unit testing of the flight software. Unit test procedures (CSU-level), CSU-to-CSU interface, CSC-level, and CSC-to-CSC interface tests will not be a deliverable to NASA; however, they shall be made available to NASA upon request via **DRD CEV-T-007**, *Software Development Folders*. The Contractor's software test plan shall be documented in **DRD CEV-T-052**, *Software test Plan*. All CSCI-level test procedures shall be documented in **DRD CEV-T-053**, *Software Test Description*. The Contractor shall document test results in **DRD CEV-T-054**, *Software Test Report*. The Contractor shall develop and deliver **DRD CEV-T-017**, *Certification Data Package* for each CSCI and for the integrated flight software. The Contractor shall develop and deliver **DRD CEV-T-040**, *Acceptance Data Package* for each flight software deliverable.
- b) The Contractor shall perform unit testing of the Flight Support software. Unit test procedures (CSU-level), CSU-to-CSU interface, CSC-level, and CSC-to-CSC interface tests will not be a deliverable to NASA; however, they shall be made available to NASA upon request via **DRD CEV-T-007**, *Software Development Folders*. The Contractor's software test plan shall be documented in **DRD CEV-T-052**, *Software test Plan*. All CSCI-level test procedures shall be documented in **DRD CEV-T-053**, *Software Test Description*. The Contractor shall document test results in **DRD CEV-T-054**, *Software Test Report*. The Contractor shall develop and deliver **DRD CEV-T-017**, *Certification Data Package*, for each GSE software CSCI and the integrated GSE software. The Contractor shall develop and deliver **DRD CEV-T-040**, *Acceptance Data Package*, for each Flight Support GSE software deliverable.

Crew Exploration Vehicle – (CEV)

Modification 904

- c) The Contractor shall perform unit testing of the FTA software. Unit test procedures (CSU-level), CSU-to-CSU interface, CSC-level, and CSC-to-CSC interface tests will not be a deliverable to NASA; however, they shall be made available to NASA upon request via **DRD CEV-T-007**, *Software Development Folders*.
- d) The Contractor shall develop and maintain **DRD CEV-T-057**, *Software Version Description Document*.
- e) In support of the Flight Test Program, **DRD CEV-T-D005**, *FTA Validation and Verification Data Book*, for Flight Test Article related software.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-007: Software Development Folder
- DRD CEV-T-040, Acceptance Data Package
- DRD CEV-T-051: Software Inspection and Peer Review Report
- DRD CEV-T-052: Software Test Plan
- DRD CEV-T-053: Software Test Description
- DRD CEV-T-054: Software Test Report
- DRD CEV-T-057 Version Description Document

The following software specific information is collected in the DRDs identified in Section 10.2

- DRD CEV-T-017: Certification Data Package

The following software specific information is collected in the DRDs specified in Section 10.6.4:

- DRD CEV-D-005: Flight Test Article (FTA) Validation and Verification Data Book

6.5.5 Independent Validation and Verification

This Contractor shall plan, coordinate and conduct independent software validation and verification throughout the software development lifecycle.

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| Crew Exploration Vehicle – (CEV)

7 RESERVED

Attachment J-1

Modification ~~9~~⁹⁴

NNJ06TA25C

| Crew Exploration Vehicle – (CEV)

8 RESERVED

Attachment J-1

Modification ~~9~~⁹⁴

NNJ06TA25C

| Crew Exploration Vehicle – (CEV)

9 RESERVED

Attachment J-1

Modification ~~9~~⁹⁴

10 CEV TEST AND VERIFICATION

Test and Verification includes the activities, hardware, and software required to manage the CEV Project verification, certification, and acceptance processes and execute the integrated spacecraft and multi-system testing and verification, including flight testing. Planning and execution (including the hardware and software used for execution) of testing and verification at the module, subsystem and component levels is contained in Sections 2 and 6.

10.1 Test and Verification Management and Administration

CEV Test and Verification Management and Administration includes the efforts for planning, organizing, directing, coordinating, controlling, and approval processes used to accomplish CEV Test and Verification objectives.

- a) The Contractor shall provide information and technical data to support NASA's completion of a National Environmental Policy Act (NEPA) analysis for the CEV project in accordance with NPR 8580.1, Implementing the National Environmental Policy Act and Executive Order 12114.

10.2 Verification Management

CEV Verification Management consists of defining and managing the policy, requirements, and processes for verifying that the CEV meets Project requirements. This covers the work to certify the CEV System by inspection, demonstration, simulation, analysis and/or test. Verification Management includes development of a plan for the verification and certification of the CEV System (hardware, firmware, and software) and associated subsystems and components. For Orion verification tests involving significant government furnished assets and in some case crewmembers, the testing roles and responsibilities will be as listed in table 10. 1

Test Type	NASA responsibilities	Contractor Responsibilities
NBL Demonstrations	<ul style="list-style-type: none"> Leads testing event Integrates test objectives Provides test crew, EVA suits, EVA umbilicals, basic Orion mockup structure Responsible for cost of test facility time 	<ul style="list-style-type: none"> Provides test engineering data, necessary design data, Orion mockup hardware specific to Orion EVA verification requirement testing, and engineering support during test preparation and execution. Provides procedures with use of Crew test participants specific to Orion verification test objectives. Responsible for engineering analysis necessary for verification requirement closure.
JSC Orion Mockup Tests/ Demonstrations Orion Vehicle Qual. Tests (Plumbrook SPF)	<ul style="list-style-type: none"> Provides flight and ground crew for test, EVA/pressure suits, EVA umbilicals, and basic Orion mockup structure Responsible for cost of test facility time 	<ul style="list-style-type: none"> Leads testing event, integrates test objectives, and provides crew training for test assets Provides procedures with use of Crew test participants specific to Orion verification test objectives. Provides high fidelity hardware specific to verification test objectives and not

CAIL Testing with Crew-in-the-Loop (Orion Project testing only)		<p>already intrinsic to the test article, such as high fidelity hatches on a mockup or non-GFE stowage items.</p> <ul style="list-style-type: none"> Responsible for engineering analysis necessary for verification requirement closure.
Post-landing Tests/Demonstrations with Crew-in-the-Loop (Orion Project testing only)	<ul style="list-style-type: none"> Provides flight and ground crew for test, EVA/pressure suits, EVA umbilicals, and basic Orion mockup structure Responsible for cost of test facility time 	<ul style="list-style-type: none"> Leads testing event, integrates test objectives, and provides crew training specific to the test event. Provides crew procedures specific to Orion verification test objectives. Provides high fidelity hardware specific to verification test objectives, such as high fidelity hatches or non-GFE stowage items. Responsible for engineering analysis necessary for verification requirement closure.
Post-landing Tests/Demonstrations with Crew-in-the-Loop (CxP Integrated testing)	<ul style="list-style-type: none"> Leads testing event Integrates test objectives Provides flight and ground crew for test, EVA/pressure suits, EVA umbilicals, and basic Orion mockup structure Responsible for cost of test facility time 	<ul style="list-style-type: none"> Provides test engineering data, necessary design data, Orion hardware specific to Orion post-landing verification requirement testing, and engineering support during test preparation and execution. Provides crew procedures specific to Orion verification test objectives. Responsible for engineering analysis necessary for verification requirement closure.
CAIL-ESTL Testing involving other Cx Projects	<ul style="list-style-type: none"> Leads testing event Integrates test objectives Provides flight and ground crew for test, EVA/pressure suits, EVA umbilicals, ESTL and CAIL facilities Responsible for cost of test facility time 	<ul style="list-style-type: none"> Provides crew training and crew procedures specific to the Orion test objectives. Provides test configuration data and required Orion test hardware not specified as GFE on J-11, J-12 for Orion verification test objectives Provides engineering support during test preparation and execution, and closure of verification requirement satisfied by the Orion test objectives.

Table 10.1 CEV Verification Roles and Responsibilities

10.2.1 Verification Requirements and Integration

- a) The Contractor shall develop a plan for the verification and certification of the CEV System (hardware and software) and associated subsystems and components by inspection, demonstration, analysis, and test in accordance with **DRD CEV-T-015, Master Verification Plan**. The plan shall address the requirements defined in CXP-72097, Constellation Master Integration and Verification Plan.

Crew Exploration Vehicle – (CEV)

Modification 904

- b) The Contractor shall document the verification method for each CEV System level requirement and all lower-level requirements in a verification matrix. The matrix will be included as part of the corresponding specification, requirements, or interface document.
- c) The Contractor shall develop and execute a Spacecraft Master Verification Plan for the verification, qualification, certification, and acceptance of the CEV Spacecraft system, modules, subsystems, and components. The Contractor shall use **DRD CEV-T-015, Master Verification Plan**, to develop the Spacecraft Master Verification Plan. The Contractor may use multiple volumes in the development of the Spacecraft Master Verification Plan to document the module, subsystem, and component level verification plans.
- d) The Contractor shall develop, update, and implement a GSE MVP for the approach, requirements, implementation strategies and associated test documentation to test, verify, activate, and qualify Contractor-provided GSE in accordance with **DRD CEV-T-015, Master Verification Plan**.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-015: Master Verification Plan

10.2.2 Integrated Vehicle Certification and Acceptance

- a) The Contractor shall develop Certification Plans per **DRD CEV-T-016** for CEV equipment. The Contractor shall deliver Certification Data Packages per **DRD CEV-T-017** and Certification Approval Requests per **DRD CEV-T-018** in preparation for design certification milestones.
- b) The Contractor shall accomplish qualification of the CEV System and its hardware and software elements in accordance with CXP-70036, Constellation Environmental Qualification and Acceptance Testing Requirements (CEQATR) Document as defined in **DRD CEV-T-015, Master Verification Plan**. Through rigorous testing, the Contractor shall confirm that the CEV System can deliver the planned performance over its expected service life when exposed to levels of stress with qualification margin above that defined in the predicted non-operating and operating environments and conditions. Qualification by methods other than test shall be described in the Certification Plan and be approved by the Government.
- c) The Contractor shall accomplish acceptance testing of each flight hardware item delivered in accordance with the CXP-70036, Constellation Environmental Qualification and Acceptance Testing Requirements (CEQATR) Document, including functional testing of each hardware and software operating mode at the most stressing operating conditions, environmental testing at the maximum predicted non-operating and operating environments and final functional testing.
- d) The Contractor shall define pass-fail criteria or acceptance tolerance bands, based on requirements.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-016: Certification Plans
- DRD CEV-T-017: Certification Data Package
- DRD CEV-T-018: Certification Approval Request

Crew Exploration Vehicle – (CEV)

Modification 994

The following integrated vehicle certification and acceptance information is collected in the RD specified in Section 10.2.1

- DRD CEV-T-015: Master Verification Plan (MVP)

10.2.3 Program Integrated Verification Support

- The Contractor shall participate with Constellation Program SE&I in the development of integrated verification plans involving multiple systems across the Constellation Program.
- The Contractor shall participate in integrated verification activities involving multiple systems across the Constellation Program including necessary in-space communication systems in accordance with CXP-70008, Constellation Master Integration and Verification Plan.
- The Contractor shall participate in the development of integrated verification plans with the ISS Program.
- The Contractor shall participate in integrated verification activities with the ISS Program and in-space communication systems as required in the CXP-70031, International Space Station (ISS) to Crew Exploration Vehicle (CEV) IRD.

10.3 Integrated Test and Verification

Integrated Test and Verification consists of all tasks associated with ground testing at the integrated vehicle (multiple modules or multiple subsystems) level and verifying that the integrated vehicle meets applicable Project requirements. The test facilities and labs include hardware and software produced for integrated ground testing of high-fidelity hardware provided by the CM and SM development teams (see Section 6). The test facilities and labs also provide for internal and external interface testing for risk reduction.

10.3.1 Integrated Vehicle Hardware Testing

- The Contractor shall plan and conduct integration and interface checkout testing to assure the assembly has been completed successfully and that hardware and software functional performance meets requirements.
- The Contractor shall use flight-qualified software during verification testing of all subsystems and components.
- The Contractor shall perform qualification tests using **DRD CEV-T-037, Qualification Test Procedures**, and document the test results in **DRD CEV-T-038, Qualification Test Report**, and **DRD CEV-T-017, Certification Data Package**. The Contractor shall perform qualification testing at the CEV Spacecraft system, and intermediate levels of assembly as necessary to accumulate the data necessary for CEV Spacecraft certification. The Contractor shall produce a Certification Data Package for the spacecraft. The Contractor shall produce a Certification Data Package for each subsystem (end-to-end). The Contractor shall deliver Certification Approval Requests per **DRD CEV-T-018** in preparation for design certification milestones. Note: Software test documentation is handled in SOW section 6.5.4, CEV Software T&V. The contractor shall develop a dedicated qualification vehicle (CM/SM/inert LAS) for system-level qualification testing. Following the completion of system-level qualification testing, the contractor shall maintain configuration control of the dedicated qualification vehicle and store it in an environmentally-controlled and access-controlled area.
- The Contractor shall perform acceptance testing at the spacecraft level using **DRD CEV-T-039, Acceptance Test Procedures**, and document the results using **DRD CEV-T-040**,

Crew Exploration Vehicle – (CEV)

Modification 904

Acceptance Data Package. An Acceptance Data Package shall be produced for the spacecraft.

- e) The Contractor shall hold Test Readiness Reviews (TRRs) before all formal verification activities. The Contractor shall make spacecraft-level test procedures available to NASA two weeks prior to each TRR. The Contractor shall invite NASA to witness all formal verification activities, including TRRs and test executions.
- f) NASA will provide facilities with the capabilities to conduct, performance/functional, EMI/EMC, Shock, Sinusoidal/Random Vibration Vibro-acoustics and System Thermal Vacuum testing to expected maximum predicted environment levels with appropriate margins.
- g) The Contractor shall verify software-controlled interfaces using flight-qualified software.
- h) The Contractor shall conduct systems tests of the total spacecraft with the flight-qualified hardware and software.
- i) The Contractor shall conduct tests of ground-based CEV software/hardware systems that interface with flight systems using interface test equipment that has been shown to be a valid emulation of the flight systems before connecting with the flight systems.
- j) The Contractor shall conduct tests using flight-qualified hardware and software for final acceptance of the ground-based CEV software/hardware systems used to perform launch and flight operations.
- k) The Contractor shall include the following types of tests in their program: (1) ground, (2) flight, (3) development, (4) item, (5) functional, (6) Integration, (7) Hardware-In-the-Loop (HWIL), (8) Software-In-the-Loop (SIL), (9) Human-in-the-Loop, (10) nonoperating environment, (11) operating conditions & environment, (12) acceptance, and (13) qualification. The Contractor shall document the test and verification program in the **DRD CEV-T-015, Master Verification Plan**.
- l) The Contractor shall provide support in order to conduct verification testing of all interface designs and requirements within the Spacecraft for those verification activities that are NASA led in NASA facilities with NASA Mockups and Contractor supported.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-037: Qualification Test Procedures
- DRD CEV-T-038: Qualification Test Report
- DRD CEV-T-039: Acceptance Test Procedures
- DRD CEV-T-040: Acceptance Data Package

The following Integrated Vehicle Hardware Testing specific information is collected in the DRD specified in Section 10.2.2.

- DRD CEV-T-015: Master Verification Plan (MVP)
- DRD CEV-T-017: Certification Data Package
- DRD CEV-T-018 Certification Approval Requests

10.3.2 Avionics and Software Testing

Avionics and Software Testing consists of all tasks associated with integrated testing of CEV avionics and software conducted in the CEV Avionics Integration Laboratory (CAIL), including hardware/software integration (HSI) testing. The element includes all hardware and software produced exclusively to support CAIL testing, with the exception of high-fidelity hardware provided by the Module development teams.

- a) NASA will lead, and the Contractor shall participate in, the development of detailed requirements for the CEV Avionics Integration Lab (CAIL). The purpose of the CAIL is to perform integration testing of the CEV avionics hardware and software and associated internal and external CEV interfaces using flight avionics hardware, flight software, and an appropriate suite of certified ground support tools/systems and software. The Contractor shall document the CAIL requirements in **DRD CEV-T-082, Spacecraft Test & Verification Facility System Requirements Document**, the CAIL design in **DRD CEV-T-083, Spacecraft Test & Verification Facility System Design Document**, the CAIL certification plan in **DRD CEV-T-084, Spacecraft Test & Verification Facility Certification Plan**, and the CAIL certification results in **DRD CEV-T-085, Spacecraft Test & Verification Facility Certification Package**.
- b) The Contractor shall develop a CAIL that at a minimum includes the following:
- A certified flight hardware suite representing the CEV Spacecraft avionics (down to the firmware-level).
 - A simulator (including hardware, software, and interfaces) certified to represent the flight environment needed to verify the end-to-end performance of the data processing system.
 - Test capabilities to perform integrated verification.
 - Provide connectivity to the Electronic Systems Test Laboratory (ESTL) to support C&T RF testing
 - Integration of the above items.
 - Interfaces to Constellation element emulators.
 - Integration of the above items.
- c) The Contractor shall develop, install, certify, and deliver the CAIL, including all applicable operating procedures, instructions, and drawings, to NASA. The CAIL shall include two full operational rigs and a third development rig
- d) The Contractor shall design the CAIL to be reconfigurable for all spacecraft configurations.
- e) The Contractor shall deliver the following:
- CAIL

Acceptance Data Packages (DRD CEV-T-040)

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-040, Acceptance Data Package
- DRD CEV-T-082: Spacecraft Test & Verification Facility System Requirements Document
- DRD CEV-T-083: Spacecraft Test & Verification Facility System Design Document
- DRD CEV-T-084: Spacecraft Test & Verification Facility Certification Plan
- DRD CEV-T-085: Spacecraft Test & Verification Facility Certification Package

10.3.3 Integrated EPS Testing

System-level Integrated EPS Testing consists of all tasks associated with integrated test and verification of the CEV CM/SM Electrical Power System (EPS) in the Exploration EPS Testbed (EEST). The EEST includes all hardware and software produced exclusively for testing hardware provided by the CM and SM development teams.

Crew Exploration Vehicle – (CEV)

Modification 904

- a) The Contractor shall develop capabilities for testing power quality of the total CM/SM EPS, from power source outputs to electrical load connections, when interfaced with CM/SM internal and external hardware emulators, an EPS subset of ground support equipment, and EPS software.
- b) The Contractor shall perform requirements development (with NASA participation and concurrence), design, integration, certification, and delivery of the EEST. The Contractor shall document the CEV EEST requirements in **DRD CEV-T-082**, *Spacecraft Test & Verification Facility System Requirements Document*, CEV EEST design in **DRD CEV-T-083**, *Spacecraft Test & Verification Facility System Design Document*, CEV EEST certification plan in **DRD CEV-T-084**, *Spacecraft Test & Verification Facility Certification Plan*, and the CEV EEST certification results in **DRD CEV-T-085**, *Spacecraft Test & Verification Facility Certification Package*.
- c) The Contractor shall develop an EEST that at a minimum includes the following.
 - o CEV electrical test bed design for integrated power quality testing in a NASA-provided and -operated facility.
 - o Flight-like power generation, storage, and distribution/control hardware; however, emulators that provide flight-like performance can be substituted for the power generation and storage hardware as defined by test objectives.
 - o Flight-like CEV power interfaces to the EPS (includes interfaces with flight/flight-like electrical loads).
 - o Electrical load emulators (including hardware, software, and interfaces) that provide flight-like performance
 - o Test capabilities to perform integrated verification and-accommodate the electrical testing of the following.
 - CEV contractor-provided equipment
 - Integrated or portable internal/external GFE and payload electrical equipment
 - CEV electrical interfaces required for ground maintenance, launch support, and other in-flight vehicles
 - Capabilities for nominal and off-nominal testing (includes destructive testing with provisions to isolate and protect the integrity of the test-bed)
 - CEV-integrated EPS with critical test-point measurements without adversely affecting flight-like performance
 - Integration of the above items.
 - Capabilities for command/control and testing of CM/SM Subsystems power quality within the scope of capabilities developed for CM/SM EPS testing.
- d) The Contractor shall develop, install, certify, and deliver the certified EEST with all applicable operating procedures, instructions, and drawings, to NASA.
- e) The Contractor shall design the EEST to be reconfigurable for all spacecraft configurations.
- f) The Contractor shall deliver the following:
 - o EEST
 - o Acceptance Data Packages (**DRD CEV-T-040**)
 - o EEST DD250

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-040, Acceptance Data Package
- DRD CEV-T-082: Spacecraft Test & Verification Facility System Requirements Document
- DRD CEV-T-083: Spacecraft Test & Verification Facility System Design Document
- DRD CEV-T-084: Spacecraft Test & Verification Facility Certification Plan

- DRD CEV-T-085: Spacecraft Test & Verification Facility Certification Package

10.3.4 Other Integrated Subsystem Testing

- a) The Contractor shall conduct verification testing of all interface designs and requirements within the spacecraft (between modules, between subsystems, and between components).

10.3.5 Interface Testing

Interface testing consists of risk reduction testing for both external (with other Constellation elements), and internal (inter-module) interfaces. Interface verification testing is conducted by the modules (see Section 6). The element includes development, maintenance, and management of unique test hardware.

10.3.5.1 Internal Interface Testing

Internal Interface testing consists of risk reduction testing for internal (inter-module) interfaces. Interface verification testing is conducted by the modules (see Section 6).

- a) The Contractor shall conduct verification testing of all interface designs and requirements within the spacecraft (between modules, between subsystems, and between components).

10.3.5.2 External Interface Testing

External Interface testing consists of risk reduction testing for external (with other Constellation elements) interfaces. Interface verification testing is conducted by the modules (see Section 6).

- a) The Contractor shall support the Government in defining test objectives.
- b) The contractor shall support NASA in the development of Bi-Lateral Exchange Agreements and Joint Test Plans.
- c) The Contractor, in conjunction with NASA, shall allocate the functional, performance and Operational requirements contained in CEV System Requirements Document, CxP 72000, and Constellation External Interface Requirements.
- d) The Contractor shall support the Government in the development and maintenance of all detailed documentation for test activities to include specifications, design, implementation, interface definitions, test and qualifications documentation on test articles and drawing trees.
- e) For the joint Constellation element tests, the Contractor shall support periodic Technical Reviews, Plan and Procedure Reviews, and Test Readiness Reviews.
- f) The Contractor shall support the Government in the development and maintenance of the test procedure documentation for test activities.
- g) The Contractor shall support the Government during test preparation, execution, and post-test tasks. The Contractor shall provide support for the test execution. This includes console support at the launch site for all training events required to certify console operators, combined systems tests in support of test preparation, and test preparation through test configuration break operations. The Contractor shall be available real time with technical and quality resources to provide test execution and resolve deviations or anomalies as they may occur.
- h) The Contractor shall support the Government in the development and maintenance of the test reporting documentation including data assessment and archive for test activities.

10.3.5.3 Interface Test Equipment/Emulators

- a) The Contractor shall conduct tests of ground-based CEV software/hardware systems that interface with flight systems using interface test equipment that has been shown to be a valid emulation of the flight systems before connecting with the flight systems.
- b) The Contractor shall develop, deliver, and sustain CEV System functional and physical interface simulator(s) and emulator(s) in compliance with the relevant Interface Control Document (ICD) requirements for use by other Constellation projects (including CLV and LSAM) to produce and evaluate the element interfaces to the CEV. The Contractor shall include operating instructions for the interface simulator(s) and emulator(s) in the **DRD CEV-T-040, Acceptance Data Package(s)** delivered with the simulators and emulators.
- c) The Contractor shall verify the CEV spacecraft with physical and functional simulators and emulators prior to integration with the other Constellation elements. The Contractor shall define requirements for Constellation element-provided physical and functional interface simulators and emulators. Physical and functional interface simulator and emulator requirements shall be delivered in accordance with **DRD CEV-T-031, CEV <Level> Requirements Specification** and **DRD CEV-T-029, Interface Control Documents** for ground support equipment. The Contractor shall develop and maintain **DRD CEV-T-035, Interface Requirements Document** for each **DRD CEV-T-029, Interface Control Document**.
- d) The Contractor shall develop, deliver, and sustain functional and physical interface simulator(s) and emulator(s) in compliance with the relevant ICD requirements for use by the ISS Program to produce and evaluate ISS interfaces to the CEV. The Contractor shall include operating instructions for the interface simulator(s) and emulator(s) in the **DRD CEV-T-040, Acceptance Data Package(s)** delivered with the simulators and emulators.
- e) The Contractor shall verify the CEV spacecraft with physical and functional simulators and emulators prior to integration with the ISS. The Contractor shall define requirements for ISS-provided physical and functional interface simulators and emulators. Physical and functional interface simulator and emulator requirements shall be delivered in accordance with **DRD CEV-T-031, CEV <Level> Requirements Specification**, and **DRD CEV-T-029, Interface Control Documents** for ground support equipment.
- f) The Contractor shall deliver CEV emulators, and DD250, (including target processor and flight software) for interface testing, as required in Section 2.3.
- g) NASA will lead and the Contractor shall participate in the Post Landing verification activities.
- h) The Contractor shall verify the CEV spacecraft with physical and functional joint test activities with Crew in suits in simulated operational donning and doffing of suits and egress /ingress and suit retrieval events with both contractor and GFE supplied equipment prior to integration with the ISS.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-040: Acceptance Data Packages
- DRD CEV-T-031, CEV <Level> Requirements Specification for ground support equipment simulators and emulators
- DRD CEV-T-029, Interface Control Documents for ground support equipment simulators and emulators.
- DRD CEV-T-035: Interface Requirements Specifications

10.3.6 Program Integrated Test Support

- a) The Contractor shall support Level 2 (Constellation) inter-project testing for CARD requirements verification and Program-level risk mitigation.
- b) The Contractor shall support an integrated stack Ground Vibration Test (GVT) at MSFC in accordance with CxP 72234, Integrated Vehicle Ground Vibration Test Task Plan.(and associated Children documents as specified in Attachment J-3, Applicable Guidance and Informational Documents List). **Support for Integrated Vehicle Ground Vibration Test shall be in accordance with the Ares IVGVT & Orion BEA.**

10.3.7 Verification Analysis and Trades

- a) If the Contractor utilizes modeling and simulation to conduct analysis in support of verification specification compliance at the integrated spacecraft level (Sections 2 and 6 address module and subsystem levels), the Contractor shall comply with **DRD CEV-T-001**, *Integrated Models, Simulations and Support Plan*, and **DRD CEV-T-002**, *CEV Engineering Models*.

10.4 Facilities

This section consists of all activities needed to provide the Integration, Test, & Verification facilities required to complete integrated verification of the spacecraft. This consists of test and verification facility hardware and software needed to support integrated CEV testing involving multiple subsystems and modules. This does not include test article and test support hardware and software. Outfitting, test article and test support hardware and software is contained in Sections 10.3 and 6.

10.4.1 Reserved

10.4.2 Reserved

10.4.3 Other Facilities

- a) The Contractor shall provide the integration, test, & verification facilities required to test and certify the integrated CEV spacecraft. The Contractor shall invite NASA to witness all subsystem facility design reviews and certification activities.
- b) The Contractor shall provide the Integration, Test, & Verification (IT&V) facilities required to complete integrated verification of the integrated CEV spacecraft. The requirements for the IT&V facilities shall be derived from the products developed under Section 10.1, Test and Verification Management and Administration
- c) Reserved
- d) The Contractor shall perform requirements development (with NASA participation and concurrence), design, integration, delivery of manufacturing, assembly and test equipment,

Crew Exploration Vehicle – (CEV)

Modification 994

verification, validation, qualification, and certification of manufacturing, assembly, and contractor test facilities. The Contractor shall document the CEV facility requirements in **DRD CEV-T-082**, *Spacecraft Test & Verification Facility System Requirements Document*, the facility design in **DRD CEV-T-083**, *Spacecraft Test & Verification Facility System Design Document*, the facility certification plan in **DRD CEV-T-084**, *Spacecraft Test & Verification Facility Certification Plan*, and the facility certification results in **DRD CEV-T-085**, *Spacecraft Test & Verification Facility Certification Package*.

- e) The Contractor shall provide support to NASA for development, design, integration, delivery of manufacturing, assembly and test equipment, verification, validation, qualification, and certification of manufacturing, assembly, and contractor test facilities (IDIQ).

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-T-082: Spacecraft Test & Verification Facility System Requirements Document
- DRD CEV-T-083: Spacecraft Test & Verification Facility System Design Document
- DRD CEV-T-084: Spacecraft Test & Verification Facility Certification Plan
- DRD CEV-T-085: Spacecraft Test & Verification Facility Certification Package

10.5 Ground Test Pathfinder Hardware

Reserved

10.6 Flight Test

All flight test activities will be managed and conducted by NASA, as a NASA-provided service to the Contractor, with support from the Contractor, for the Design, Development, Test, and Evaluation (DDT&E) phase. As the lead for this activity, NASA has defined flight tests for the Pad Abort (PA) and Ascent Abort (AA) testing of the Launch Abort Vehicle (LAV) in Table 10.1, and Ares sub-orbital and orbital flight tests in Table 10.2. The PA and AA tests are considered part of the Abort Flight Test Project (AFTP), and Ares 1Y test is considered part of the Integrated Flight Test Project (IFTP). Although it is anticipated that flight test planning, monitoring, and reporting will continue past the Ares flights, the scope of Section 10.6 of this SOW is all abort and integrated Ares flights prior to the first human launch (FHL). Tables 10.1 and 10.2 provide conceptual guidance for the complexity required for each test article, and the primary supplier of the hardware. The actual complexity required for each test vehicle will be determined by the vehicle design and the required test objectives for each test.

SOW Section 10.6 covers the work associated with pre-production fidelity test hardware furnished by the Contractor and Contractor support requirements for Government-furnished test hardware. For this effort, the Contractor will support NASA in the development of test-unique non-production and production CEV requirements as appropriate. Per Table 10.1 and 10.2, the Contractor will design, manufacture, verify, and deliver the Flight Test Articles (FTAs) appropriate for these tests. For PA-1 and AA-1, NASA shall provide the CM primary structure. The contractor shall provide the CM primary structure for PA-2, AA-2, and the remainder of the flight test program. For PA-1 and AA-1, NASA will lead the systems engineering and integration (SE&I) effort, and the assembly, integration and test/production (AIT/P) to be performed at Dryden Flight Research Center (DFRC).

Crew Exploration Vehicle – (CEV)

Modification 904

Figure 10.1, Abort Flight Test Matrix, shows the components to be used for the PA/AA flight test vehicles, and where appropriate, the primary supplier of the hardware. For the AA aborts flown on the ATB, the interface between the FTA and the ATB is between the Sep Ring and the service module sub-section (SMSS). The SMSS is an integral part of the ATB and will be provided by the government. The Sep Ring is an integral part of the FTA and is the minimum hardware required to perform the CM/SM retention and release (R&R) and umbilical disconnect functions. PA tests will consist of the FTA components without the ATB. NASA will supply the ATB used in AA tests 1-3 as identified in Table 10.1. An ATB will be supplied for the high altitude abort if the Ares launch vehicle is not available.

A test team led by NASA, with Contractor support, will coordinate the development and implementation of the AFTP and IFTP. SOW Section 10.6 also includes the Contractor support effort associated with PA-1 and PA-2, AA-1 thru AA-23, and Ares 1Y flight tests.

For the Ares 1Y flight tests, the Contractor will support NASA in the development of the test unique production CEV requirements. This requirement set will contain requirements that vary from the production CEV requirements set and configuration changes from the production CEV configuration. The requirement definition activity is covered in this section of the SOW. The design, production, assembly, checkout and delivery of the spacecraft for these tests are covered in SOW Section 6, CEV Spacecraft Development, using the modified requirements developed in this section. The Contractor operations support effort for the Orion/Ares flight tests is covered in SOW Section 2.7, Flight and Ground Operations Integration.

The test unique GSE for the flight tests is covered in SOW Section 10.6.6.9 Flight Test Ground Support Equipment; SOW section 6.1.6.2, 6.2.6.2, 6.4.6.2 Flight Test Article Design and Production. All GSE that is non-Flight Test unique is covered in Sections 2.7.2 e, 6.1.6.1, 6.2.6.1, 6.4.6.1.

The Contractor shall perform acceptance testing of Flight Test Articles document the results using **DRD CEV-T-040, Acceptance Data Package**.

Deliverables

- The Contractor shall deliver the following document(s):
- DRD CEV-T-040: Acceptance Data Package Type 4 as tailored in J-2 DPD

Table 10.2 Abort Flight Test Matrix

Test	Test Description	CM/FBC Primary Structure & Integration	SM/SR Primary Support & Integration	LAS Fidelity Support	Heat Shield TPS	Recv ² Sys	LRS	Avioni cs OFI	DFI	RCS	Int. Vehicle Health Monitors	Docking System
PA-1	0-0 Pad Abort. Early evaluation of launch abort system capability from a pad abort, WSMR test site.	T/NASA	SR ¹ T/NASA	T/LM (no BPC or fairings)	Not Req	T/NASA	Not Req	T/LM	T/NASA	Not Req	Not Req	Not Req
PA-2	0-0 Pad Abort. Validation of launch abort system capability from a pad abort, WSMR test site.	Pre-Prod/LM	SR T/NASA	P/LM	P/LM	P/NASA	TBD	T/LM	T/NASA (LM installation)	Not Req	Not Req	T/NASA (ATLAS/LIDS)
AA-1	Max Q Sep from LV. Validation of LAS capability to separate from ATB at max q based on the high-performance side of the CLV nominally dispersed trajectory. WSMR test site	T/NASA	SR T/NASA	T/LM	N/A	P/NASA	Not Req	T/LM	T/NASA	T/NA SA	N/A	Not Req
AA-2	Transonic Sep from LV. Early evaluation of LAS capability to separate from Abort Test Booster (ATB) at max drag, WSMR	Pre-Prod/LM	SR T/NASA	P/LM	P/LM	P/NASA	TBD	T/LM	T/NASA (LM installation)	TBD	T/LM	T/NASA (ATLAS/LIDS mass Simulant)

Test	Test Description	CM/FBC Primary Structure & Integration	SM/SR Primary Support & Integration	LAS Fidelity Support	Heat Shield TPS	Recv ² Sys	LRS	Avionics OFI	DFI	RCS	Int. Vehicle Health Monitors	Docking System
	test site.											
Ares-1-Y	Hi Altitude Sep from LV. Validation of LAS capability to separate from Ares LV at low dynamic pressure at conditions simulating a divergence of a malfunctioning CLV 2 nd stage (off-nominal conditions), KSC test site.	F/It-Prod LM	P/LM	F/LM	F/LM	F/NASA	TBD	F/LM (not all components)	T/NASA (LM installation)	F/LM	F/LM	T/NASA (LIDS)

Notes: 1) SR used as stand only. CM/SM R&R mechanism will not be functional. Used for qualification testing of the CM/SM R&R and umbilical disconnect mechanisms.

2) Forward Bay Cover will be provided by NASA for PA-1 and AA-1. All other flights, LM will provide the Forward Cover Assembly.

CM – Crew Module; **SM** – Service Module; **SA** – Spacecraft Adapter; **SR** – Separation Ring; **LAS** – Launch Abort System; **TPS** – Thermal Protection System; **LRS** – Landing Recovery System; **OFI** – Operational Flight Instrumentation; **DFI** – Developmental Flight Instrumentation; **RCS** – Reaction Control System; **IVHM** – Integrated Vehicle Health Monitoring; **FTA** – Flight Test Article, **T** – Test HW/SW required to conduct the test but not necessarily representing flight HW or SW in design, **P**- Prototype flight-like hardware in function, early design concept, **F** – Production quality Hardware and Software; **RECV² SYS** – Recovery Systems

NNJ06TA25C

Crew Exploration Vehicle – (CEV)

Attachment J-1

Modification ~~904~~

NNJ06TA25C

Crew Exploration Vehicle – (CEV)

Attachment J-1

Modification ~~904~~

10.6.1 Project Management and Tech Planning

Reserved

10.6.2 Flight Test Vehicle (FTV) SE&I

Reserved

10.6.3 Abort test Booster (ATB) DDT&E

Reserved

10.6.4 Flight Test Article (FTA) DDT&E

This consists of the effort to define the number, fidelity, system and interface requirements, and specifications of the FTAs necessary to complete the flight test effort. This also includes the design, development, systems engineering, integration, test, and verification of unique FTAs not provided by Section 6, CEV Spacecraft Development. Unique FT hardware manufacturing, production, and delivery is contained in Section 10.6.6.

- a) The Contractor shall refine the PA and AA tests defined in Table 10.1. The Contractor shall document the configurations in **DRD CEV-D-001**, *FTA Definition*.
- b) The Contractor shall support the Government in defining AFTP and IFTP flight test objectives.
- c) Based on the flight tests outlined in Table 10.1, Abort Flight Test Matrix, and Table 10.2, Ares Flight Test Matrix, the Contractor shall document the proposed fidelity of Contractor-furnished FTAs to complete the flight test effort and document the configurations in **DRD CEV-D-001**, *FTA Definition*.
- d) The contractor shall support NASA in the development of FTO-AFT-FTA-004, *Flight Test Article System Requirement Document*, for PA1 and AA1.
- e) The Contractor, in conjunction with NASA, shall allocate the functional, performance and operational requirements contained in FTO-AFT-FTA-004, *Flight Test Article System Requirement Document* to the Flight Test Articles and Ground Support Equipment. The Contractor shall document the requirements developed from this process in the FTA <Level> Specifications, **DRD CEV-D-002**, *Flight Test Article (FTA) <Level> Specifications*.
- f) Reserved
- g) The Contractor shall develop and maintain system requirements for PA2, and AA-2 as identified in Table 10.1, Abort Flight Test Matrix, and **DRD CEV-D-001**, *FTA Definition*. The Contractor shall deliver the requirements in **DRD CEV-D-002**, *FTA <Level> Specifications*.
- h) The Contractor shall develop and maintain module, subsystem, and component requirement specifications appropriate for Contractor-furnished hardware configuration based on the flight test objectives identified in CxP-72166, *Flight Test Vehicle Mission and Flight Objectives*, in **DRD CEV-D-002**, *FTA <Level> Specifications*. The Contractor shall make available bi-directional traceability for these requirements.
- i) The Contractor shall develop and maintain FTA specifications in **DRD CEV-D-002**, *FTA <Level> Specifications* and drawing trees for Contractor-furnished hardware and deliver them in **DRD CEV-D-004**, *FTA Engineering Design Data Book*.

- j) The Contractor shall develop and maintain all detailed documentation for Contractor-furnished flight test articles to include specifications, design, implementation, interface definitions, test and qualifications documentation on modules, subsystems, components and drawing trees and deliver them in **DRD CEV-D-004, FTA Engineering Design Data Book**. The Contractor shall support the Government in the maintenance and development of all similar related detailed documentation for Government-furnished test articles.
- k) The Contractor shall support the development of module, subsystem, and component requirement specifications appropriate for each NASA-furnished FTA configuration based on the flight test objectives.
- l) The Contractor shall develop and maintain system specifications for the FTAs for Ares/Orion flight test articles. It is expected that these FTAs will have configuration changes from the CEV System Requirements as defined in Section 2.2 CEV Requirements Definition and Management and Sections 2.2, Requirements Definition and Management 6.1.2 CM System Engineering and Integration, 6.2.2 SM and SA System Engineering and Integration, 6.4.2 LAS System Engineering and Integration. The Contractor shall document the requirements in **DRD CEV-T-031, CEV <Level> Requirements Specification**.
- m) The Contractor shall define and provide the internal interfaces requirements between each module, subsystem, and computer software configuration item as identified in **DRD CEV-D-002, Flight Test Article (FTA) <Level> Specifications**.
- n) The Contractor shall develop the module-to-module and subsystem-to-subsystem IRDs/ICDs and document in **DRD CEV-D-002, Flight Test Article (FTA) <Level> Specifications**.
- o) NASA will provide the following products to the Contractor.
 - o CxP-72167, Orion Aerodynamic Database (for all phases of flight)
 - o CxP-72168, Orion Aerothermodynamic Database (for all phases of flight)
 - o FTO-AFT-FTV-011-PA1, Orion Launch Abort Vehicle (LAV) Development Flight Instrumentation (DFI) Master Measurement List for PA-1
- p) The Contractor shall provide the installation design, associated installation hardware and installation of NASA-provided Development Flight Instruments (DFI) for the PA-1 LAS in accordance with FTO-AFT-FTA-024-PA1, FTA-to-DFI Interface Control Document.
- q) NASA will provide the Contractor the ATB-induced environments as defined in FTO-AFT-FTA-001, *Flight Test Article Environmental Requirements Document*.
- r) The Contractor shall provide NASA the CEV LAS induced environments.
- s) The Contractor shall design the FTAs for the specific natural environments and induced environments that the FTA must operate within and for which the FTA must be qualified, encompassing all phases of FTA production, testing and operation in all modes through disposal in accordance with FTO-AFT-FTA-001, *Flight Test Article Environmental Requirements Document*.
- t) The Contractor shall define the FTA System Command, Control, Communications, and Information (C3I) interoperability interfaces to be compatible with the range and document these interfaces per **DRD CEV-D-004, FTA Engineering Design Data Book**.
- u) For the Abort Test Flights identified in Table 10.1, the Contractor shall support FTA Periodic Technical Reviews, and Flight Test Readiness Reviews.
- v) The Contractor shall document production and SR&QA standards per **DRD CEV-D-004, FTA Engineering Design Data Book**.
- w) The Contractor shall ensure that the FTAs are built and tested in accordance with the Contractor's product assurance requirements and standards as documented in **DRD CEV-D-004, FTA Engineering Design Data Book**.

NNJ06TA25C	Attachment J-1
Crew Exploration Vehicle – (CEV)	Modification 60

- x) The Contractor shall document the as-built FTAs per **DRD CEV-D-004**, *FTA Engineering Design Data Book*.
- y) The Contractor shall verify the design as specified and documented in **DRD CEV-D-005**, *FTA Validation and Verification Data Book*, documenting the FTA validation and verification effort.
- z) For each Flight Test Article, the Contractor shall deliver to the NASA designated integration facility in accordance with Attachment J-9.
- aa) NASA will provide the Contractor the WSMR natural environments as defined in FTO-AFT-FTA-001, *Flight Test Article Environmental Requirements Document*.
- ab) The Contractor shall develop the Master Verification Plan Volume for the Flight Test Articles, **DRD-CEV-T-015**, *Master Verification Plan*.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-D-001: Flight Test Article (FTA) Definition
- DRD CEV-D-002: Flight Test Article (FTA) <Level> Specifications
- DRD CEV-D-004: Flight Test Article (FTA) Engineering Design Data Book
- DRD CEV-D-005: Flight Test Article (FTA) Validation and Verification Data Book
- DRD CEV-T-031: CEV <Level> Requirements Specification for the FTA
- DRD-CEV-T-015: Flight Test Article Volume Master Verification Plan

10.6.5 Flight Test Operations DDT&E (IDIQ)

Flight Test Operations DDT&E consists of the generic concepts, plans, procedures, and training for flight test operations and the design, development, systems engineering, integration, test, and verification of the ground hardware and software associated with flight test execution. The element includes all non-recurring costs associated with establishing and maintaining the flight test operations infrastructure. (IDIQ)

10.6.6 Flight Test Hardware Production

Reserved

NNJ06TA25C	Attachment J-1
Crew Exploration Vehicle – (CEV)	Modification 60

10.6.6.1 *Reserved*

10.6.6.2 *Reserved*

10.6.6.3 *Reserved*

10.6.6.4 *Reserved*

10.6.6.5 *Reserved*

10.6.6.6 *Reserved*

10.6.6.7 *Reserved*

10.6.6.8 *Reserved*

10.6.6.9 *Flight Test GSE Production*

Flight Test Article Ground Support Equipment (GSE) covered in this section includes the design, production, and delivery of the FTA-unique Mechanical GSE (MGSE) and Electrical GSE (EGSE), both hardware and associated software, needed for ground and flight operations to support all FTA components furnished by the Contractor. In addition, the GSE covered in this section includes all LAS GSE.

Note: Work associated with GSE common with the production vehicle is covered in Section 2.7.2.(e), Integrated Ground Support Equipment.

- a) The Contractor shall manufacture, deliver, and accept (including acceptance testing) the flight test GSE required for the Flight Test Program.
- b) The Contractor shall design, develop, certify, produce, and deliver GSE for FTAs for the flight test defined in **DRD CEV-D-002**, *FTA System Requirements*, and the requirements in this SOW.
- c) The Contractor shall design the GSE to support FTA C3I Interoperability interfaces to be compatible with the range and document these interfaces per **DRD CEV-D-006**, *FTA GSE Data Book*.
- d) The Contractor shall design and produce the FTA GSE required for all phases of FTA production, transportation, integration and checkout, and ground and launch processing
- e) The Contractor shall include FTA GSE in FTA Periodic Technical Reviews, FTA System Acceptance Reviews, and Flight Test Readiness Reviews.
- f) The Contractor shall document production and S&MA standards per **DRD CEV-D-006** *FTA GSE Data Book*.
- g) The Contractor shall ensure that the GSE is built and tested in accordance with the Contractor's product assurance requirements and standards as documented in **DRD CEV-D-006** *FTA GSE Data Book*.

NNJ06TA25C	Attachment J-1
Crew Exploration Vehicle – (CEV)	Modification 60

- h) The Contractor shall document the as-built FTA GSE per **DRD CEV-D-006**, *FTA GSE Data Book*.
 - i) The Contractor shall design and produce the FTA GSE required for post-test FTA safing and recovery.
 - j) The Contractor shall include FTA GSE requirements in **DRD CEV-D-002**, *FTA <Level> Specifications* and FTA GSE design in **DRD CEV-D-006**, *FTA GSE Design Data Book*.
 - k) The Contractor shall complete the DD250 for the FTA GSE and deliver the FTA GSE to the NASA- designated test facility in accordance with Attachment J-9.
 - l) The Contractor shall operate, maintain and update the FTA GSE for the duration of the flight test activity.
 - m) The Contractor shall provide procedures for the FTA GSE.
 - n) The Contractor shall provide training for the use of FTA GSE.
 - o) The Contractor shall use a ground command, telemetry, and display system that is compatible with the host range. Use of data converters is unacceptable.
 - p) The Contractor shall develop a common ground telemetry and data network that allows for software updates via the network. Sites include the Contractor's home site, the host range, and DRFC.
 - q) The Contractor shall provide the design of the ground transportation and handling (GT&H) equipment to NASA.
- Note: NASA-LaRC will build the GT&H equipment to ship the LaRC provided CMs and LAS pathfinders.
- r) The Contractor shall deliver the EGSE to the DFRC.

Deliverables

The Contractor shall deliver and maintain the following document(s):

- DRD CEV-D-002: Flight Test Article (FTA) <Level> Data Book
- DRD CEV-D-006: Flight Test Article (FTA) GSE Design Data Book

10.6.7 Abort Test Booster Production

Reserved

NNJ06TA25C	Attachment J-1
Crew Exploration Vehicle – (CEV)	Modification 60

10.6.7.1 *Reserved*

10.6.7.2 *Reserved*

10.6.7.3 *Reserved*

10.6.7.4 *Reserved*

10.6.7.5 *Reserved*

10.6.7.6 *Reserved*

10.6.8 *Flight Test Operations (IDIQ)*

Flight Test operations includes the Contractor support for the flight test activities.

Flight Test Operations include the plans, processes, schedules, and products required to perform the flight design, analyses, and flight planning activities; flight products and procedure development; and execution of flight tests through Ares-1Y. Flight Test Operations will be the responsibility of NASA; however, it is essential that the Contractor provide the data and support to NASA for the development of the flight test operations products to prepare for and execute the CEV missions.

Note: Flight Test Support for Orion flight tests are covered in Section 2.7.

- a) For PA-1 and AA-1, the Contractor shall provide side-by-side support for the LAS, the avionics sub-system, the MGSE and the EGSE. As FTAs increase in functionality and complexity (PA-2 and beyond), additional support shall be provided as appropriate. Support includes, but is not limited to, EGSE OFI telemetry database updates, EGSE software updates, and EGSE hardware spares and troubleshooting support. Avionics and LAS flight software updates, regression testing, and troubleshooting support.

Note: Consideration should be given to using Ground Operations personnel from KSC to augment the Ground Operations team at WSMR for training purposes.

- b) For PA-1 and AA-1, the Contractor shall provide initial training to NASA test team personnel on the LAS module, the CM avionics, the MGSE and the EGSE. As FTAs increase in functionality and complexity (PA-2 and beyond), additional training shall be provided as appropriate.
- c) The Contractor shall provide support for the test execution. This includes console support at the test range for all training events required to certify console operators, combined systems tests in support of launch preparation, and launch through recovery operations. This also includes the Contractor operations and maintenance of the EGSE at the test range.
- d) Reserve
- e) The Contractor shall provide support for the Post Flight Test Report.
- f) The Contractor shall provide data to NASA for range safety in accordance with Section 2.7.4, Range Safety, and **DRD CEV-O-007**, *Range Safety Requirements Documents*.
- g) The Contractor shall support NASA-provided parachute and pyrotechnic initiator integration into the FTA.

- h) The Contractor shall provide support for flight test planning, to include module and subsystem procedures, ground processing, checkout, launch, recovery and refurbishment procedures, flight rules, launch commit criteria, and minimum equipment list required for launch.

10.7 Special Projects/Studies – T&V

This section addresses unique projects or studies needed to support, facilitate, improve, or enhance CEV test and verification completeness or effectiveness.

- a) The Contractor shall perform special CEV-related studies and analyses as directed by NASA. The Contractor shall define the resources required as part of their response to NASA's request for a task order plan. The trade studies and analyses resulting from special studies shall also include the impact to system safety and life cycle cost.

10.7.1 TPS Flight Test

This is a study to determine the value, feasibility, and necessity of performing a flight test to prove the effectiveness of the TPS materials and application for lunar-return entries.

11 EDUCATION AND PUBLIC OUTREACH (IDIQ)

Education and Public Outreach incorporates the development of the Education and Public Outreach portion of the CEV Project. Provide for the EPO responsibilities in alignment with NASA's Strategic plan for Education. This includes management and coordinated activities, formal education, informal education, public outreach, media support, and web site deve

Statement of Work Annex for Recovery Funded efforts

This statement of work (SOW) is a supplement to the SOW contained in the basic contract in Attachment J-1. In as much as the work requirements in this Annex supplement and do not replace the existing SOW, all of the requirements contained in Attachment J-1 and elsewhere in the contract, remain in full force and effect.

Technical Tasks:

The contractor shall deliver work in the three categories which are Ground Test Articles, Engineering Design Units, and Technology Development Testing for Improved Crew Safety. Tasks are more specifically defined in the table below:

<u>ORION PROJECT Priority Stimulus Tasks</u>	<u>-</u>	<u>Task Description</u>
<u>NAME</u>	<u>IPT</u>	<u>-</u>
<u>-</u>	<u>-</u>	<u>-</u>
<u>GTA</u>	<u>-</u>	<u>-</u>
<u>Ground Test Article (GTA) Titanium Heat Shield</u>	<u>Crew Module</u>	<u>Complete the development of the engineering drawings for the titanium heat shields. Complete the procurement of long lead titanium material for the Ground Test Article (GTA) and engineering development unit (EDU) heat shields. Perform fabrication of tooling in support of the GTA heat shield.</u>
<u>Service Module (SM) Ground Test Article (GTA) Test Article Build & Tooling</u>	<u>Service Module</u>	<u>Perform the development of the engineering drawings for GTA Service Module (SM) Structures Tooling.</u>
<u>Service Module (SM) Ground Test Article (GTA) Engineering</u>	<u>Service Module</u>	<u>Perform the engineering development activities of the Service Module Ground Test Article Engineering.</u>

<u>EDU</u>	-	-
<u>ASIC for Time Triggered Gigabit Ethernet (TTGbe) and Vehicle Master Computer</u>	<u>Avionics & Software</u>	<u>Perform FPGA/board prototype risk mitigation testing. Complete the activities required to turn on the ASIC foundry as well as perform the build and test of a prototype SCP, NIC Switch, PDU controller with FPGA. Integrate completed items into a test network in a realistic Orion configuration. Validate requirements for components prior to ASIC IDR.</u>
<u>Avionics & Software Development & qualification tools - Verification Test Boards (VTB)</u>	<u>Avionics & Software</u>	<u>Develop design specifications, produce drawings and parts lists, install and verify the Orion Vehicle master computer Test Benches (VTBs) and the Orion Support Software Development Lab (SSDL). Perform the procurement of hardware and software for the SSDL and the rig hardware for the Orion VTBs.</u>
<u>Communication & Tracking (C&T) early sub activation</u>	<u>Avionics & Software</u>	<u>Complete the engineering specifications, request for proposals and source selection of the subcontracts for specific Communication and Tracking components. Perform long lead procurement for the transponder and baseband processor EDU's.</u>
<u>Recover CEV Avionics Integration Lab (CAIL) Development Costs in FY09 and FY10</u>	<u>Avionics & Software</u>	<u>Complete the detailed design of CEV Avionics Integration Lab software, rig subsystems and lab infrastructure. Perform the procurement of initial CAIL infrastructure and prototyping effort.</u>
<u>Textron Avcoat EDU</u>	<u>Crew Module</u>	<u>Complete the closeout of the Preliminary Design Review action items as well as the Design Analysis Cycle 4 development activities for ablative gunning and inspection and test panel fabrication and heat shield EDU manufacturing.</u>

<u>Forward Bay Cover (FBC) Retention & Release (R&R) Engineering Development Unit</u>	<u>Crew Module</u>	<u>Perform the CM Forward Bay Cover retention and release EDU hardware design development and engineering drawings for parts procurement and fabrication and test fixture design.</u>
<u>Crew Module (CM)/Service Module (SM) Retention & Release EDU</u>	<u>Crew Module</u>	<u>Perform the CM/SM retention and release EDU hardware design development and engineering drawings for parts procurement and fabrication and test fixture design.</u>
<u>Launch Abort System/Crew Module Retention & Release EDU</u>	<u>Crew Module</u>	<u>Perform the LAS/CM retention and release EDU hardware design development and engineering drawings for parts procurement and fabrication and test fixture design.</u>
<u>Hatches (Docking & Side) Engineering Development Unit (EDU)</u>	<u>Crew Module</u>	<u>Perform the CM hatch (docking and side) EDU hardware design development and engineering drawings for parts procurement and fabrication and test fixture design.</u>
<u>Crew Impact Attenuation System (CIAS) Engineering Development Unit (EDU)</u>	<u>Crew Module</u>	<u>Perform the Crew Impact Attenuation System EDU hardware design development and engineering drawings for parts procurement and fabrication and test fixture design.</u>
<u>Lexan Windows EDU</u>	<u>Crew Module</u>	<u>Perform the CM Lexan window EDU hardware design development and engineering drawings for parts procurement and fabrication and test fixture design.</u>
<u>ECLSS (SM) requirement to meet qualification deliveries - included in CM</u>	<u>Service Module</u>	<u>See CM ECLSS below</u>
<u>ECLSS (CM) requirement to meet qualification deliveries - Includes SM</u>	<u>Crew Module</u>	<u>Perform the CM/SM ECLSS EDU hardware design development and engineering drawings for parts long lead procurement and fabrication for the specific subsystems listed below: CO2 and humidity control, Vent and Temp control, Sublimator Assy, Contingency</u>

		<u>Gas analyzer.</u>
<u>CM ECLSS Paragon Long lead Procurement (integrated ECLSS design)</u>	<u>Crew Module</u>	<u>Perform the CM Umbilical Quick Disconnect design and analysis of the mechanical devices required to produce engineering development unit hardware and component qualification hardware.</u>
<u>SM ECLSS Paragon Long lead Procurement (integrated ECLSS design)</u>	<u>Service Module</u>	<u>Perform the SM Umbilical Quick Disconnect design and analysis of the mechanical devices required to produce engineering development unit hardware and component qualification hardware. Perform service module radiator development testing, preliminary design and analysis, and engineering required for production of hardware required for the Structure Test Article.</u>
<u>Station Power Transfer Unit (SPTU)</u>	<u>Crew Module</u>	<u>Perform the CM Station Power transfer unit EDU hardware design development and engineering drawings for long lead parts procurement.</u>
<u>Aerojet Long lead procurement for Hot Flow/Cold Flow Testing</u>	<u>Crew Module</u>	<u>Complete the fabrication and delivery of the CM reaction control system Cold flow development test article (CFDTA) and Hot Fire Test Article (HFTA).</u>
<u>Crew Module Uprighting System (CMUS) EDUs & Long Lead Procurement</u>	<u>Crew Module</u>	<u>Perform the CMUS EDU hardware design development and engineering drawings for long lead procurement of two inflation tanks (mass emulators) and 1 CMUS EDU.</u>
<u>Service Module Fairing Separation Test Tooling and Panels</u>	<u>Service Module</u>	<u>Complete the design and development of the specific tooling and panels for the service module fairing separation test.</u>

<u>Service Module Propulsion Recovery</u>	<u>Service Module</u>	<u>Perform the engineering and drawings for the service module pressurization system isolation valves and the associated procurement to support the cold gas and hot fire tests of the Orion Main engines.</u>
<u>Technology Development Testing for Improved Crew Safety</u>	-	-
<u>Material Testing for Thermal Protection System</u>	<u>Crew Module</u>	<u>Perform material testing for the crew module thermal protection system.</u>
<u>Segmented Crew Module (deferred tooling)</u>	<u>Crew Module</u>	<u>Complete the design and development of the specific tooling and handling fixtures for the segmented crew module design.</u>
<u>Materials & Processing (M&P) for Titanium Fasteners and 2050 Aluminum</u>	<u>Crew Module</u>	<u>Complete material testing of titanium 2050 fasteners for the crew module.</u>

Reporting:

In addition to the above tasks, there are reporting requirements that are in addition to those called for by FAR 52.204-11. The contractor shall provide both financial reporting as well as technical progress reports. The above tasks are more broadly associated with satisfaction of established contract requirements and deliverables, but are delineated above to provide appropriate segregation for the expenditure of ARRA funding, as well as to facilitate reporting as required by the use of the funds. The above tasks are delineated to allow the Contractor to provide information regarding measurable performance against the task schedules and requirements.

The financial reporting shall be in the form of a supplemental report submitted in conjunction with the NF533. LM shall provide the details by Stimulus Category (GTA, EDU, Crew Safety) in the 533 format which include labors hours and total cost, which includes subcontractors and materials. The contractor is required to report the Cost/Hrs in 3 areas (Current actuals, Cum actuals, and Current estimate). Based on Recovery Requirements, dollars shall be tracked, reported, and invoiced separately and shall not be comingled with other funding. For transparency and traceability, the Stimulus Categories shall be identified by WBS Level 2/3 in order split Cost/WYE between by Project CAM.

The contractor shall also provide monthly Recovery Act progress reports. These reports must describe the cumulative progress made, plans forward and shall also describe any difficulties encountered. Progress made shall be estimated and reported using milestone percent complete reporting. The progress reported must not be percent hours exhausted, percent cost incurred, or earned value based. The final report provided shall describe not only work complete but also shall document how this activity has reduced the overall risk to the project and shall also document the way in which lessons learned as the result of these activities have been incorporated into the design and manufacturing efforts.

Statement of Work Annex for Recovery Funded efforts

This statement of work (SOW) is a supplement to the SOW contained in the basic contract in Attachment J-1. In as much as the work requirements in this Annex supplement and do not replace the existing SOW, all of the requirements contained in Attachment J-1 and elsewhere in the contract, remain in full force and effect.

Technical Tasks:

The contractor shall deliver work in the three categories which are Ground Test Articles, Engineering Design Units, and Technology Development Testing for Improved Crew Safety. Tasks are more specifically defined in the table below:

ORION PROJECT Priority Stimulus Tasks	-	Task Description
NAME	IPT	-
-	-	-
GTA	-	-
Ground Test Article (GTA) Titanium Heat Shield	Crew Module	Complete the development of the engineering drawings for the titanium heat shields. Complete the procurement of long lead titanium material for the Ground Test Article (GTA)

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Attachment J-1

Crew Exploration Vehicle – (CEV)

Modification 7694

		and engineering development unit (EDU) heat shields. Perform fabrication of tooling in support of the GTA heat shield.
Service Module (SM) Ground Test Article (GTA) Test Article Build & Tooling	Service Module	Perform the development of the engineering drawings for GTA Service Module (SM) Structures Tooling.
Service Module (SM) Ground Test Article (GTA) Engineering	Service Module	Perform the engineering development activities of the Service Module Ground Test Article Engineering.

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Attachment J-1

EDU	-	-	
ASIC for Time Triggered Gigabit Ethernet (TTGbe) and Vehicle Master Computer	Avionics & Software	Perform FPGA/board prototype risk mitigation testing. Complete the activities required to turn on the ASIC foundry as well as perform the build and test of a prototype SCP, NIC Switch, PDU controller with FPGA. Integrate completed items into a test network in a realistic Orion configuration. Validate requirements for components prior to ASIC IDR.	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab
Avionics & Software Development & qualification tools—Verification Test Boards (VTB)	Avionics & Software	Develop design specifications, produce drawings and parts lists, install and verify the Orion Vehicle master computer Test Benches (VTBs) and the Orion Support Software Development Lab (SSDL). Perform the procurement of hardware and software for the SSDL and the rig hardware for the Orion VTBs.	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab
Communication & Tracking (C&T) early sub activation	Avionics & Software	Complete the engineering specifications, request for proposals and source selection of the subcontracts for specific Communication and Tracking components. Perform long lead procurement for the transponder and baseband processor EDU's.	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab

Recover CEV Avionics Integration Lab (CAIL) Development Costs in FY09 and FY10	Avionics & Software	Complete the detailed design of CEV Avionics Integration Lab software, rig subsystems and lab infrastructure. Perform the procurement of initial CAIL infrastructure and prototyping effort.	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab
Textron Avcoat EDU	Crew Module	Complete the closeout of the Preliminary Design Review action items as well as the Design Analysis Cycle 4 development activities for ablative gunning and inspection and test panel fabrication and heat shield EDU manufacturing.	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab
Forward Bay Cover (FBC) Retention & Release (R&R) Engineering Development Unit	Crew Module	Perform the CM Forward Bay Cover retention and release EDU hardware design development and engineering drawings for parts procurement and fabrication and test fixture design.	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab
Crew Module (CM)/Service Module (SM) Retention & Release EDU	Crew Module	Perform the CM/SM retention and release EDU hardware design development and engineering drawings for parts procurement and fabrication and test fixture design.	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab
Launch Abort System/Crew Module Retention & Release EDU	Crew Module	Perform the LAS/CM retention and release EDU hardware design development and engineering drawings for parts procurement and fabrication and test fixture design.	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab

Hatches (Docking & Side) Engineering Development Unit (EDU)	Crew Module	Perform the CM hatch (docking and side) EDU hardware design development and engineering drawings for parts procurement and fabrication and test fixture design.	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab
Crew Impact Attenuation System (CIAS) Engineering Development Unit (EDU)	Crew Module	Perform the Crew Impact Attenuation System EDU hardware design development and engineering drawings for parts procurement and fabrication and test fixture design.	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab
Lexan Windows EDU	Crew Module	Perform the CM Lexan window EDU hardware design development and engineering drawings for parts procurement and fabrication and test fixture design.	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab
ECLSS (SM) requirement to meet qualification deliveries included in CM	Service Module	See CM ECLSS below	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab
ECLSS (CM) requirement to meet qualification deliveries Includes SM	Crew Module	Perform the CM/SM ECLSS EDU hardware design development and engineering drawings for parts long lead procurement and fabrication for the specific subsystems listed below: CO2 and humidity control, Vent and Temp control, Sublimator Assy, Contingency Gas analyzer.	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab
CM ECLSS Paragon Long lead Procurement (integrated ECLSS design)	Crew Module	Perform the CM Umbilical Quick Disconnect design and analysis of the mechanical devices required to produce engineering development unit	Formatted: Centered, Indent: Left: 0.5", Don't adjust space between Latin and Asian text, Don't adjust space between Asian text and numbers, Tab stops: 0.5", List tab

		hardware and component qualification hardware.
SM ECLSS Paragon Long lead Procurement (integrated ECLSS design)	Service Module	Perform the SM Umbilical Quick Disconnect design and analysis of the mechanical devices required to produce engineering development unit hardware and component qualification hardware. Perform service module radiator development testing, preliminary design and analysis, and engineering required for production of hardware required for the Structure Test Article.
Station Power Transfer Unit (SPTU)	Crew Module	Perform the CM Station Power transfer unit EDU hardware design development and engineering drawings for long lead parts procurement.
Aerojet Long lead procurement for Hot Flow/Cold Flow Testing	Crew Module	Complete the fabrication and delivery of the CM reaction control system Cold flow development test article (CFDTA) and Hot Fire Test Article (HFTA).
Crew Module Uprighting System (CMUS) EDUs & Long Lead Procurement	Crew Module	Perform the CMUS EDU hardware design development and engineering drawings for long lead procurement of two inflation tanks (mass emulators) and 1 CMUS EDU.
Service Module Fairing Separation Test Tooling and	Service Module	Complete the design and development of the specific tooling and panels for the

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Panels		service module fairing separation test.
Service Module Propulsion Recovery	Service Module	Perform the engineering and drawings for the service module pressurization system isolation valves and the associated procurement to support the cold gas and hot fire tests of the Orion Main engines.
Technology Development Testing for Improved Crew Safety	-	-
Material Testing for Thermal Protection System	Crew Module	Perform material testing for the crew module thermal protection system.
Segmented Crew Module (deferred tooling)	Crew Module	Complete the design and development of the specific tooling and handling fixtures for the segmented crew module design.
Materials & Processing (M&P) for Titanium Fasteners and 2050 Aluminum	Crew Module	Complete material testing of titanium 2050 fasteners for the crew module.

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Reporting:

In addition to the above tasks, there are reporting requirements that are in addition to those called for by FAR 52.204-11. The contractor shall provide both financial reporting as well as technical progress reports. The above tasks are more broadly associated with satisfaction of established contract requirements and deliverables, but are delineated above to provide appropriate segregation for the expenditure of ARRA funding, as well as to facilitate reporting as required by the use of the funds. The above tasks are delineated to allow the Contractor to provide information regarding measurable performance against the task schedules and requirements.

~~The financial reporting shall be in the form of a supplemental report submitted in conjunction with the NF533. LM shall provide the details by Stimulus Category (GTA, EDU, Crew Safety) in the 533 format which include labors hours and total cost, which includes subcontractors and materials. The contractor is required to report the Cost/Hrs in 3 areas (Current actuals, Cum actuals, and Current estimate). Based on Recovery Requirements, dollars shall be tracked, reported, and invoiced separately and shall not be comingled with other funding. For transparency and traceability, the Stimulus Categories shall be identified by WBS Level 2/3 in order split Cost/WYE between by Project CAM.~~

~~The contractor shall also provide monthly Recovery Act progress reports. These reports must describe the cumulative progress made, plans forward and shall also describe any difficulties encountered. Progress made shall be estimated and reported using milestone percent complete reporting. The progress reported must not be percent hours exhausted, percent cost incurred, or earned value based. The final report provided shall describe not only work complete but also shall document how this activity has reduced the overall risk to the project and shall also document the way in which lessons learned as the result of these activities have been incorporated into the design and manufacturing efforts.~~